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A preliminary study of Demand-side Management techniques in a building

Advisor:
Prof. Davide Papurello

Candidate:
Pasquale Parisi

Politecnico
di Torino

Abstract

Looking at the current historical period it is easy to see that we are in the midst of the energy transition. In fact, in this historical period in Europe we can see a greater penetration of renewable sources to the detriment of fossil fuel sources which today are the main responsible for the increase in greenhouse gases. This energy transition towards renewables, along with the production of greenhouse gases, is also taking away the flexibility of energy demand as most renewable sources do not allow any flexibility on energy production and this unfortunately makes energy management more difficult. An aid to energy management is represented by Demand-side Management (DSM) which today not only represents one of the most economically and energetically advantageous methods but also one of the few strategies that can be implemented immediately with a zero investment and therefore with an instant return on investment.

The purpose of this work is to study the air conditioning of the energy center of the Polytechnic of Turin from an energy, economic and social point of view through different DSM strategies that can be implemented in the present (2022) and in a future scenario in the second phase of the energy transition (2030 and 2040). To carry out this work, the energy sources used in the energy center were first studied, followed by a study on the continuity of the related energy sources during the energy transition from 2020 to 2040. Subsequently, the monitoring of the building air conditioning was studied and finally various DSM strategies were provided with their relative strengths and weaknesses.

The main conclusions reached thanks to the data provided by the highly sophisticated detectors of the energy center and thanks to the meteorological station of the Polytechnic of Turin are two. The first refers to summer air conditioning and the second to winter air conditioning. In summer air conditioning, in the summer condition it was thought to delay the air conditioning and cancel the post heating if it is possible to achieve thermal comfort without it, in this way an average daily saving of approximately 55% of energy. In winter, however, it was not possible to have an average daily saving of the building through DSM, on the contrary an increase in consumption of about 5.5% was estimated, however if we look at the entire energy picture we note that the economic and consequently energy gain on the part of the seller is great, therefore if the seller share part of his profits with the buildings that carry out this strategy, can start a business where overall energy is saved and overall the seller and users earn there

Acknowledgements

This master's degree thesis for me represents the arrival at one of the greatest goals of my life. If I had to describe the experience, I had I would describe it as a journey containing climbs, descents, traps, positive and negative surprises. There were very important moments in this journey that formed me a lot because they touched all the emotions that are present in my heart. There have been moments of happiness shared with people close to me and there have been moments of sadness shared with people even closer.

So the first thanks go to these people who are the most important people for me. I'm talking about my girlfriend Ale who has always been at the forefront for me since she has been present, supporting me both in the best and the hardest moments. My whole family who have supported me both financially and personally since the day I was born. In particular I remember:

My mother who taught me to question what is studied thus stimulating the same interest as the person who wrote the study. My father who taught me that what fills life are experiences and good times. My older sister Panzi showed me what it takes to find happiness. My older brother Emanuele who taught me to verify sources before starting a scientific study. My middle sister Stella who showed me how the advantages and disadvantages of a life where you always try to climb. The sister of my same age Caccola whom we grew up together, where the experiences were carried out in parallel independently, but she was always at the forefront in talking about the evolution of inner growth. The last people in my family that I would like to thank are my grandparents who rest in peace. They have all had a great influence on me. One taught me the importance of family, the other the dedication to work and the last one simply gave me love.

The last part of the thanks goes to my friends. Ceci who reminded me of the taste of clean air. Fede Tav who when I know him has always been a point of reference. Antonio Col who has always been close to me during my growth and Giorgia who has always been present and absent at the same time.

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Summary

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1. Introduction

“Demand-side management” (DSM), also known as “Demand-side flexibility” or “Load Management”, can be defined as :

“technologies, actions and programmes on the demand-side of energy meters that seek to manage or decrease energy consumption, in order to reduce total energy system expenditures or contribute to the achievement of policy objectives such as emissions reduction or balancing supply and demand.” (Warren. P. [25]).

In order to analyze the potential of the DSM it is necessary, first of all, to have an idea about the flexibility and limits on the energy supplier side. In fact, knowing that flexibility on the energy supplier side decreases, the potential for flexibility on the demand side increases. In fact, with the increase in the penetration of renewable sources (which often have no flexibility) there is a clear idea that the DSM strategies will have more and more potential for energy flexibility while the potential for flexibility on the energy manager side will decrease.

However, the increase in generation from renewable sources is not always synonymous with an increase in the penetration of renewable sources as the penetration of renewable sources or the ratio between green energy produced and total energy produced also depends on the total energy produced that a in turn it depends on other factors such as population, economic growth etc. Therefore, in order to study the potential of the DSM, it is therefore necessary to also study the global energy geopolitical situation as these two things are indirectly connected.

Some references that study the world energy situation are the "World Energy Model" developed by the Interination Agency of Energy IEA and the "Global Multi- regional Markal ”developed by the Word Energy Council (WEC). The study is clear, it predicts a sharp increase in world demand, particularly from emerging economies and those that are expected to emerge in the short future [26,27]. This increase is due both to the growth of the world population which is projected to be 2 million (25%) by 2050 [1], [2]and to the growth in per capita demand in emerging economies

However, to reduce the impact that energy demand has on the plant, as also discussed by the Paris agreements renewed in 2015 and signed by 195 countries, we are committed to reducing the production of greenhouse gases in such a way as to limit the average increase. temperature below 1.5 C by 2050.

Fortunately, the growing economic competitiveness of renewable resources with respect to fossil fuels, in particular solar and wind power, allows for the effective implementation of Paris agreements.

It is important to specify this novelty as for the realization of energy it is not only important to comply with the regulations in force but also the economic balance is very important. In fact, for investors, an energy source must simultaneously respect three forms of sustainability: social, economic and environmental as shown in the figure1-1.

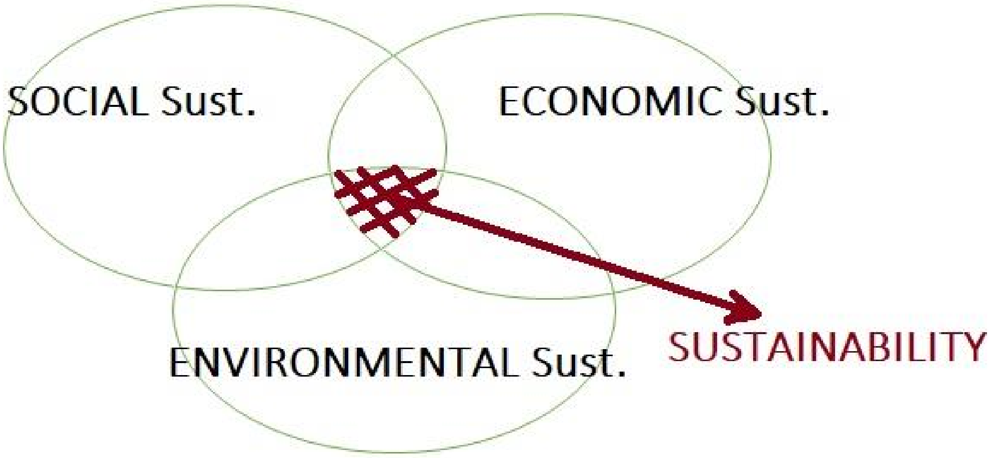

Figure 1-1 The set of the three sustainability

The Paris agreements, as already mentioned, limit the possible supplies of energy in these do not are in the sustainable environmental sector and influence the socially sustainable sector; So very often it is not possible to reach an agreement between social, environmental and economic sustainability. However, aid is provided. The aids are usually state incentives that thanks to national policies help to make renewable sources economically sustainable and therefore obtain an sustainable energy source as shown in figure.

Although renewable energy sources are currently starting to be competitive with fossil fuel energy source, unfortunately, these advances are not yet sufficient, according to IEA [11] the world community is not fully meeting the various annual targets, so there is a need for a change of course which includes a even greater impact of eco-sustainable energy and a gradual reduction of oil, coal and natural gas as soon as possible.

In addition , the growth in the penetration of renewables brings with it numerous disadvantages. One of the most important is certainly the lack of energy flexibility as renewable energy is not produced on demand like traditional energy sources but is produced independently of the energy demand from environmental factors. This problem generates now but even more in the future an imbalance in the balance between supply and demand.

The problem about the balance of electric grid is today solved with conventional methods (so fossil fuel power plants) or with a storage energy source such as hydroelectricity. In fact , the question is reached second by adding the amount of uncontrollable energy (such as renewable energy) with the controllable energy count (such as energy from fossil fuels or hydrolectricity).

In the future it is expected that the flexibility of energy peaks will be managed less and less by fossil fuels and more and more by eco-sustainable storage energy sources such as: An increase in hydroelectric storage, or through currently unconventional forms of storage such as: Compressed Air Energy Storage - CAES, Liquid Air Energy Storage -LAES, Energy vault towers, electric batteries, thermal batteries etc ..

The interest of demand management has been a topic that has been extensively discussed over the past 20 years. To date, in fact, it is common to calibrate electric hot water boilers or household appliances in order to make them turn on when energy costs less and therefore when demand is at a minimum.

Managing energy peaks is very difficult and above all economically disadvantageous. For example, a hydroelectric storage system has a charge and discharge cycle efficiency of 50% [28]. Therefore, for the energy demand in the peaks of maximum energy, double the theoretical energy must be used as half of the energy will be lost in the charge and discharge cycle of the storage.

Demand-side Management (DSM) helps to solve this problem not from the point of view of supply but from the demand; it therefore takes care of lowering the energy peaks or, if possible, of chasing the energy demand curve as much as possible, minimizing the adaptation of the demand curve.

So, as will be discussed in the following work, lowering energy peaks brings with it numerous advantages such as:

- Reduction of investments required for energy storage
- Avoid using fossil fuel power plants to meet peak loads
- Supporting an ever better penetration of renewable energies taking into account their variability
- Reduction of greenhouse gas emissions related to energy production
- It encourages market competition between different flexibility resources (encourages demand to adapt to supply in such a way as to increasingly rely on renewable sources, taking into account their regularities and irregularities).

The study objective presented is to investigate energy and / or economic savings according to Demand-side Management practices using as a reference a building that has systems for the production and management of the latest generation of energy where to meet its energy needs it uses different forms of energy thus becoming a model of regional, national and international importance. The reference building is therefore the Energy Center of the Polytechnic of Turin.

In the final part of this chapter it is very important to introduce the next chapters. They will be described in sequence:

- **Context of demand management**: In this chapter we will analyze what the most important political actions that have led to the development of the DSM and the actions related to them have been and why they have occurred. The evolution of the main DSM strategies in different European countries will be analyzed to make a comparison and finally the policies related to the DSM of the Italian state will be carefully studied. In addition describes how the impact of the Russia-Ukraine conflict energetically impacted all of Europe and especially Italy. This chapter also sets out the response that Europe has adopted to safeguard itself energetically. An important note is that this chapter was inserted later after the study of future scenarios had already been carried out.
- **Study of the energy situation:** Energy situations and their impact on pollution over the last 30 years will be analyzed. This chapter will briefly talk about the world and European situation and in a profound way of Italy and Turin. The study also hypothesizes how the national energy mix will change in Italy in the different seasons and hour by hour during the day and subsequently a feasibility study will be performed for certain technologies in Turin over time.
- **Theoretical aspects of buildings:** shows the concept of Demand-side Management and how this concept could help to achieve future goals. In particular, it describes demand response technologies and focuses on DSM strategies, analyzing them one by one. subsequently explains what the connection with the administration of buildings with energy implementations is. This chapter shows you step by step what the procedures are necessary to start the DSM and finally analyzes the key roles that can take responsibility for these operations.
- **Case study: Energy center:** in this chapter, the reference building or the Energy Center is analyzed in detail, a brief introduction to the building is carried out and then immersed in the ternicus. The forms of self-consumption installed and their final uses (experimental or economic) are studied. With the help of the air conditioning project, the geometric and structural characteristics of the building were analyzed and then the seasonal consumption

due to air conditioning was analyzed. Subsequently, a feasibility study was carried out over time of the air conditioning technologies used by the building

- **Implementations through the DSM**: This chapter discusses the major implementations that could be performed through DSM policies. This chapter discusses what the real problems are to undertake this strategy in the case of using them for the Energy Center
- **conclusions**: This chapter is the final chapter. This chapter summarizes the strengths and weaknesses of adopting DSM policies in Italy in the present and hypothesizes what the possible DSM strategies can be and what the possible technologies with which they can be adopted may be

2. Context of demand management

2.1 Great Political Strategies

Even before the Kyoto protocol of 1997, energy saving policies began, this is because before the Kyoto protocol international markets had experienced several energy crises, the most important was in 1973 following the Iranian revolution. Thanks to these energy crises, it was realized that an internal production of energy would have several advantages. So from 1973 research on alternative energy sources and energy saving methods began. Over the decades, renewable energy sources for energy production and strategies such as the DSM for energy saving became established.

Today we identify the DSM as an energy saving strategy born from a series of policies over decades that have led to innovative ways of saving energy (a fundamental step to reduce the environmental impact).

Another push towards the start of renewable energy beyond the 1973 energy crisis was the HSE 88-001 report series from 198. In this 1986 report it is scientifically explained that humanity is not only influencing climate change. but that this action is currently irreversible; therefore, it will not be possible to arrive at the pre-industrial climate but the only possibility is to slow down the trend of climate change. On the basis of this document, there was the Rio Earth Summit (1992) and later in 1997 the Kyoto Protocol was stipulated.

The Kyoto Protocol required:

- Developed countries to limit their GHG emissions in 2012, as compared to their emissions in 1990.

- Provides detailed methods and mechanisms for how the emission reductions can be achieved, measured and verified.

- All members in UNFCCC have not agreed to sign the Kyoto Protocol

- Adopted in 1997, but entered into force on February 16th, 2005

In the European Union, the Biofuel Directive (2003/30 / CE) and Energy Taxation Directive (2003/96 / EC) are stopped. Which respectively promote the use of biofuels and other renewable fuels for transport and the latter ensures the functionality of the EU internal energy market to avoid distortions of competition through different tax systems.

The Kyoto protocols were subsequently replaced. The reason for this event is partly due to the fact that countries that did not reach the set goals were not required to pay any penalties; therefore, this protocol did not incentivize the world enough. For this in 2015, 195 countries signed the Paris agreements.

The European Union is currently at the forefront of the energy transition towards renewable sources, in fact the aim is therefore to reach an eco-sustainable energy market, to do this we need to find a way to produce energy with a net emission of greenhouse gases equal to zero. in order to avoid even greater global changes. Therefore, thanks to the Paris agreements, a guideline has been drawn [1] up to be followed in order to reach zero net emissions of CO2 equivalent in 2050.

In order to plan the achievement of net zero CO2 emissions in 2050 and to complete the energy transition, it was necessary to program a guideline for the achievement of the objectives . The graph below (Figure2-1) shows an estimate of the evolution of CO2 produced in the EU during the energy transition.

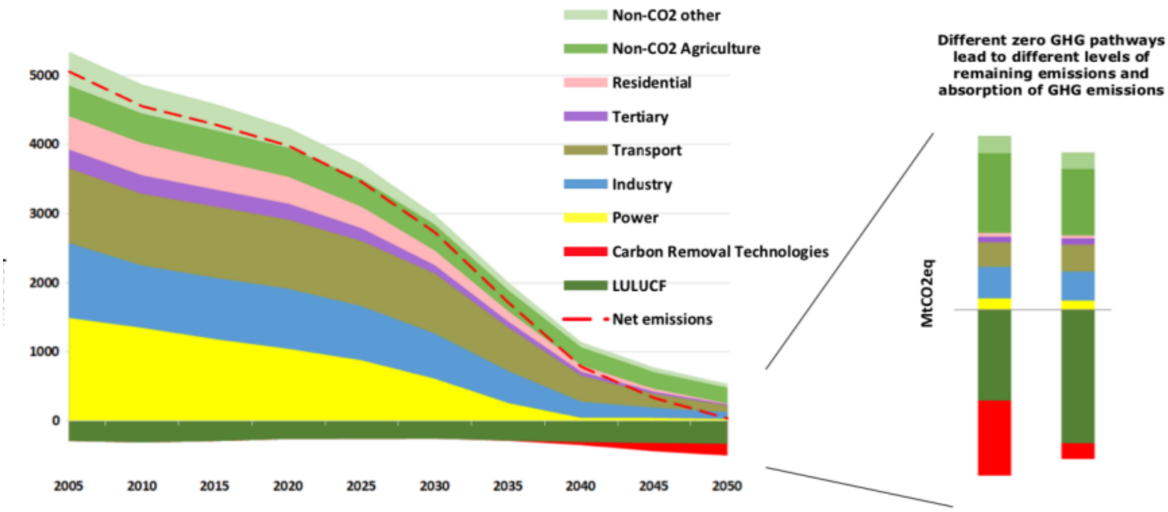

Figure 2-1 GHG emissions trajectory in a 1.5 °C scenario

The graph shows on the abscissas from date while on the ordinates the mega tons of CO2 equivalent produced in a year by the European Union. Depending on the colors, the sectors where the decrease is expected are also distinguished. Currently about two thirds of emissions are caused by energy production, in the industrial sector and in the transport sector.

To follow the aforementioned guideline, the Climate and Energy Package was adopted in 2009. It is a set of EU legislative measures, designed to reach three core targets by 2020 (known as the "20-20-20 by 2020"):

- 20% reduction in EU greenhouse gas emissions from 1990 levels;
- 20% increase in the share of EU energy consumption produced from renewable resources;
- 20% improvement in the EU's energy efficiency
- ... furthermore, 10% biofuels in transport sector
- It contains four core legislative acts:
- The revised Emissions Trading System (EU ETS) Directive
- the Effort Sharing Decision (ESD)
- the Renewable Energy Directive and
- the Carbon Capture and Storage Directive

While looking at Europe, it can be said that the 2020 objectives have been achieved; in fact, we note that 21 out of 26 member states have reached their targets set by the European Union. The countries that have not made it are: Cyprus, Finland, Germany, Ireland, Bulgaria and Malta. As far as Italy is concerned, we note that it has abundantly achieved its objectives. Also thanks to the lockdown due to Covid-19 which has helped to reduce CO2 emissions.

The Union European understand that the trend for 2030 was not sufficient as these policies and targets are projected to reach reductions of greenhouse gas emissions of around -45% by 2030 and around -60% by 2050. This is not sufficient for the EU to contribute to the long- term temperature goas set in Paris Agreement then the targets of the Paris Agreement are increase with the Fit for 55 plan

To date, the Fit for 55 goals for 2030 are [3]:

- Reduction of net greenhouse gas emissions by 55%
- An increase in renewable energies in the energy mix to 40%
- Energy efficiency increase of 36% for final energy consumption
- 39% increase in energy efficiency for primary energy consumption

As if that were not enough, in 2022 a new world energy crisis arose due to the conflict between Russia and Ukraine, the European response from the energy point of view was to replace the Fit for 55 plan with the REPowerEU .

The current plan shows some differences with the old one. In fact, we have [4]:

- The increase of renewable energies in the energy mix rises to 45%
- Natural gas in the energy mix decreases by 48% compared to the Fit-for-55 scenario
- Coal consumption increased by 41% compared to the Fit-for-55 scenario

The figure2-2 [5] compares the primary energy of the European energy mix in 2019 with an estimate of primary energy consumption in 2030 according to the Fir for 55 and the REPowerEU .

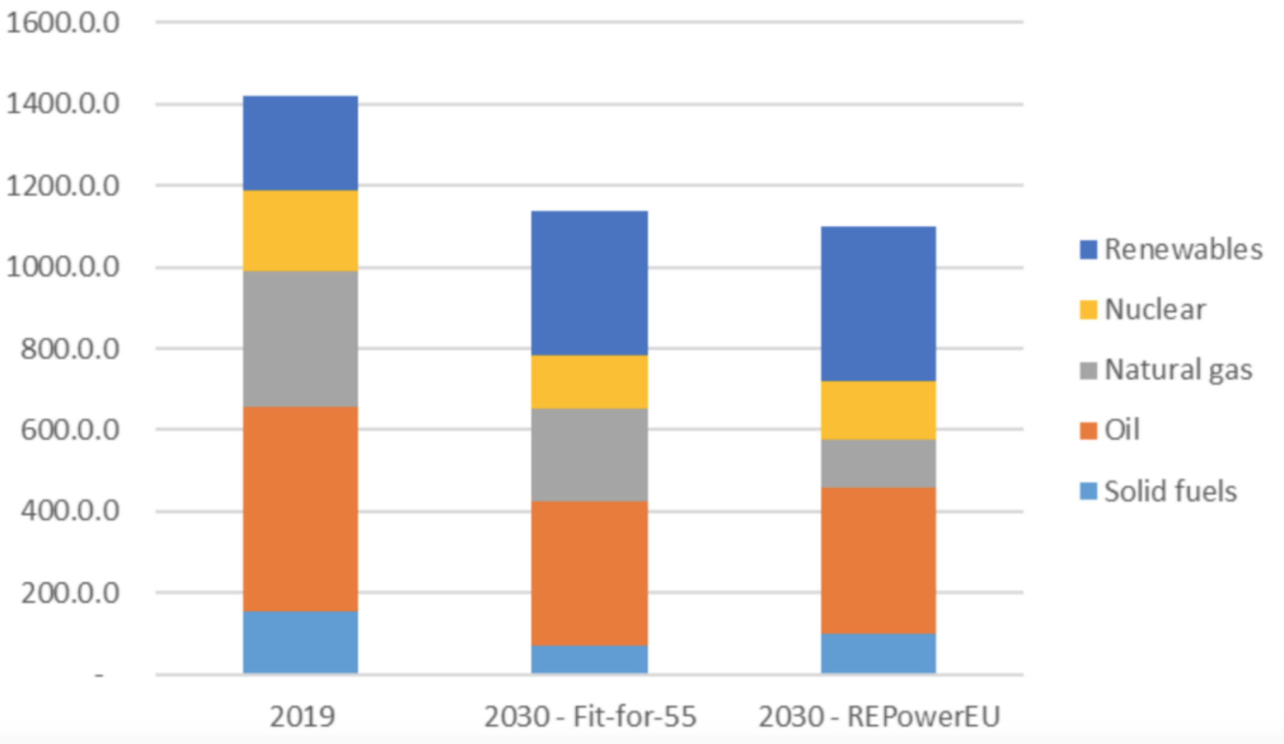

Figure 2-2 comparison between the energy mix of 2019 with the fit for 55 and the RepowerEU

The policies mentioned above are the most important policies they have and are affecting the energy transition. In fact, they are very important to estimate the importance of the DSM as global and European policies are indirectly connected to energy saving methods and above all from policies it is possible to estimate the evolution of DSM technology during the energy transition as we will see. during the report.

2.2 Policies related to DSM techniques

Over the years in Europe there has been a gradual energy saving, this result has occurred despite economic growth, which generally provides for an increase in energy demand. This decrease in energy demand came thanks to directives (started after the Kyoto protocol) that pushed the market to ever greater development in the energy field.

Among the strategies used is that of energy saving, which are linked to DSM techniques. The graph below (Figure 2-3) gives an idea of which directives are allowing the energy transition in Europe in their time frame.[6]

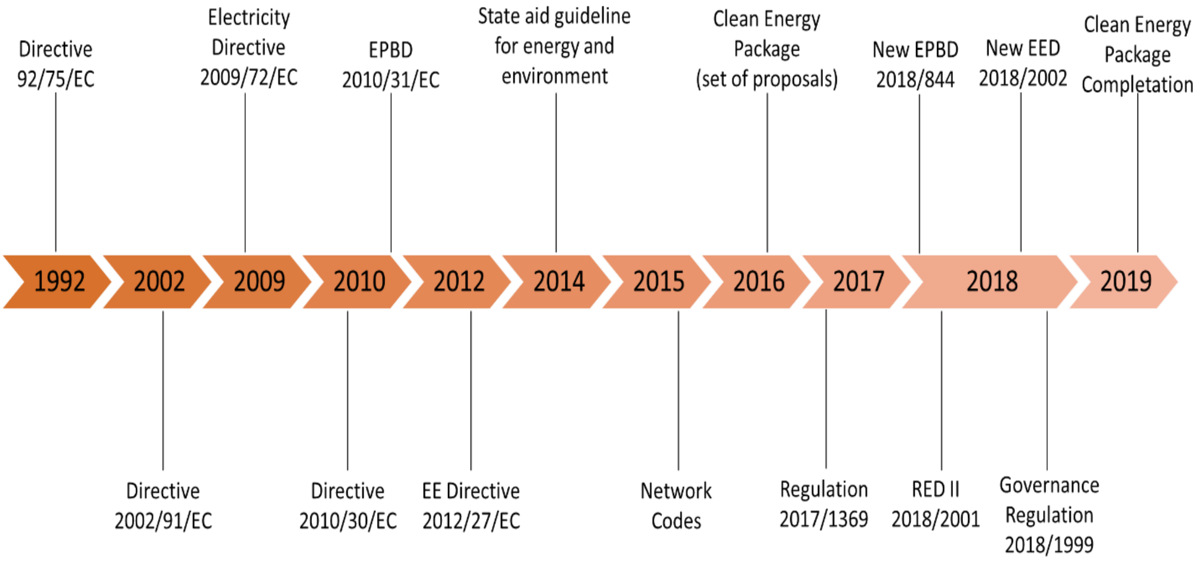

Figure 2-3 A succession of directives over time

A very important feature of these Directives that we are going to analyze is that very often the new directive enhances or replaces its predecessor. Therefore the directives shown in the figure show both new energy efficiency measures and evolutions of the same measures.

A very important directive is **Directive 92/75** [1]**/ EC** (later repealed by **Directive 2010/30 / EU** and then by **Regulation** [2]**2017/1369** which introduced and subsequently changed the energy labeling of energy products [6]. The function of this directive is to assign a label for each household appliance, this label contains a letter which, depending on the value, determines the energy efficiency of the appliance. In this way, the consumer can easily know which appliance has a higher efficiency and therefore save money. bill and at the same time contribute to increasing energy efficiency. This directive has helped to decrease the European and national energy trend . This simple label (which from 1995 to 2021 went from A +++ to D) has started a cycle of replacement for appliances, as to have long-term savings, the most performing appliances replace the less perfect ones mooring. To date, the legislation on the label has for the first time greatly evolved in fact all the household appliances that are sold in Europe have changed their meaning again as the evolution of technology has made it possible that over 99% of household appliances have a performance from A to higher. The reason why the directive on the label has had to evolve is due to the improvement and efficiency of household appliances in fact, if a class A appliance at the exit of the legislation represented a very performing appliance, in 2022 at the end of the legislation, the class A represents a non- energetically performing household appliance . In addition, the psychological factor must be added where for the human mind the class A is always a symbol of high class and this pushed buyers to make a wrong choice during the purchase. With the new directive, the energy classes go from A to G, the new scale follows different parameters and compared to the first it is also shifted, in fact an old class A + appliance takes only the F position of the new energy class.

As regards buildings, a very important directive is the **directive on the energy performance of buildings (EPBD**) with directive 2002/91 / EC replaced by directive 2010/31 / EU [17] which certifies a class ranging from A4 to G for a total of 10 classes which, depending on how much the building disperses and the primary energy sources it disperses, represents the energy class of the building.

Paying attention to Italy, we note that the vast majority of buildings have a very low energy class, among the last three (E, F , G), as if that were not enough Italy after the 90s saw a crisis in the sector of construction, in addition it must always deal with the historical problem of tax evasion and with the lack of amnesties (as often the buildings do not respect the cadastral plan). Therefore the Italian

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[11] The Directive is a legislative act of the European Union that establishes objectives and goals that the Member States should pursue, but leaves them the identification of suitable methods.

[2] The regulation is a piece of legislation of the European Union that the Member State must receive and apply as it was drafted.

state, pushed by European directives, has always tried to restart construction and at the same time to reduce the energy consumed by buildings during the winter (in accordance with the Paris agreements) and to solve other internal problems related to Italy has seen a growing increase in state incentives such as the restructuring bonus and / or eco-bonus ranging from 50 to 110%.

In 2009 the European Union introduced to the concept of DSM is the Electricity Directive (2009/72 / EC) which belongs to the Third Energy Package of the EU. It provides a definition for the management between demand and energy efficiency. In fact , paraphrasing the article we have:

" *energy efficiency / demand side management": a comprehensive or integrated approach aimed at influencing the quantity and timing of electricity consumption in order to reduce primary energy consumption and load peaks by giving priority to investments in energy efficiency measures, o other measures, such as interruptible supply contracts, with respect to investments to increase generation capacity, if the former represent the most effective and economical option, taking into account the positive environmental impact of reducing energy consumption and the safety aspects of the " procurement and related distribution costs;* "(Art. 2.29).

The EU therefore recognized the DSM strategy as an important alternative to the new generation capacity and recognized its contribution to the achievement of environmental objectives and its positive effect linked to the reduction of energy consumption and the decrease in demand in peak loads. (thermal or electric) specified in articles 3.2, 8, 25.7.

Another European directive related to the aspects of the DSM is the Energy Efficiency Directive (2012/27 / EU) which establishes a common framework for EU states to meet the energy targets of 2020 and to continue beyond that date. This directive strengthened the building objectives (EPBD) in order to encourage major renovations and define strategies for the renewal of the national building stock, pushing public buildings to play an exemplary role from an energy point of view (Article 5). In addition, each EU member is expected to establish energy efficiency obligations of 1.5% per year until 2020.

Currently, the **guidelines on State aid for Energy and the Environment (2014-2020) and the proposals of the European Green Deal** proposed by the European Commission, also call for alternative ways to achieve generation adequacy, including the DSM.

Therefore, the new proposals and the approved regulation follow four main objectives related to the consumer such as:

- Facilitate the production of one's own energy and manage it in the best possible way;
- Active participation also through demand- response services directly or by aggregation;

- Be more involved in the system and be able to respond to price signals;
- Adoption of intelligent technologies, improvement of energy consumption and comfort.

A fairly recent legislation is the so-called **Clean Energy Package** . The EU clean energy package, proposed by the European Commission in November 2016, includes eight legislative texts on the electricity market and consumers, on the energy efficiency of buildings, on the sustainability of renewable energy and bioenergy, on a European regulation of 'electricity and a preparation for the European energy risk [7].

In this regard, the approved regulation follows four main objectives related to the consumer:

- Facilitate the production of one's own energy and manage it in the best possible way
- Active participation also through demand- response services directly or by aggregation
- Be more involved in the system and be able to respond to price signals
- Adoption of intelligent technologies, improvement of electricity consumption without decreasing the service rendered

Great attention should be paid to the two interventions of the Clean Energy Packege on the internal electricity market. The intention is to redesign both the wholesale and retail electricity markets with the ultimate goal of putting the final consumer in a more central role. This proposal allows the consumer to participate in the electricity market and increase its flexibility. This process would lead to consumer empowerment and could even increase the share of renewables. With regard to wholesale electricity, in order to make prices more reflective of the real value, the removal of maximum prices has been proposed. Implementation of this proposal would greatly increase the DSM and electricity storage strategies .

With the planned interventions, each consumer will be able to actively participate in the market and offer demand side response services, receiving (depending on the contract) an advantageous remuneration.

It is important to note that some directives have not yet been approved even if the proposed law was made in late 2016, while others such as Directive (EU) 2018/2001 which concerns the achievement of Renewable Energy of 32.5% in the European energy mix. for 2030 it was replaced by Fit-for-55 for 2030 with a target of 40% and subsequently by REPower which sets this target at 45% by 2030.

2.3 State of development of DSM in the EU

The directives discussed in the previous paragraph were issued with the intention of moving all EU members in a single common direction. However, for social and environmental reasons we note that the way in which member states arrive at the goals differ from each other and sometimes these goals are not even achieved.

According to a JRC study [8], the authors divided EU countries into three groups with respect to the state of their regulation regarding Demand Renspose .

- First group: Includes those countries that have not adequately engaged in the field of DSM. In these countries the directives and therefore the respective European obligations have been received formally but there has not yet been adequate implementation of these obligations. In other words, it means that these countries allow for demand response policies but there are no regulatory frameworks that allow demand-side resources to enter the market so that there is an economic gain. This group includes: Bulgaria, Croatia, Cyprus, Italy, Malta, Estonia, Latvia, Lithuania, Portugal, Czech Republic, Slovakia, Spain and Hungary
- Second group: Includes those countries that have enabled demand Response only through the reseller. This means that they limit aggregators to the role of service providers for resellers rather than independent parties providing independent offers to consumers. This choice limits the market offers and does not always benefit the consumer. From the customer's point of view, no clear value will be offered for their flexibility, but they will have a pay in the bill. The consumer can choose whether to accept this variable form of market to refuse. The countries in this group are: Australia, Germany, the Netherlands and the Nordic countries.
- Third group: includes those member states that allow both demand response and independent aggregation. These markets represent the most developed in Europe even if they still present some problems that can be solved. This group includes: Belgium , France, Ireland and the United Kingdom.

As just mentioned, France is one of the European countries that has developed Demand Response for energy saving. In fact, it has adopted the so-called Tempeo -tariffs since 1995 . This type of rate combines the structures of Time-of-use (TOU) and Critical peak pricing (CPP). It also considers three types of days during the year, dividing each day into two periods thus obtaining the total of six price levels. Each day of the year is assigned a color whose quantity of days is pre -programmed while the type of day is assigned the day before. So it is possible to distinguish:

- Red days: less frequent and high price

- White days: average price
- Blue days: which represent the cheapest and most frequent days.

It is a very effective program that has presented considerable savings on consumers both from an energy and an economic point of view.

Another highly developed market is Finland. It has:

- single tariff (adopted by 10% of the population)
- Season and day /night Time-of-use rates (adopted by 80% of the population)
- Real Time Pricing rates which is based on the wholesale market price. It requires the installation of a smart meter to allow the consumer to pay for electricity at an hourly rate

Taking a very rough summary we can see which states do demand response and how. The table2-1 therefore summarizes the European countries on demand response .

Table 2-1 DSM strategies for electricity in European countries

Types of dynamic tariffs	**Member states**
Seasonal	FR, HU, PT, RO, UK
Peak	BE, HR, CZ, DK, FI, FR, DE, HU, IE, IT, LV, LT, NL, PT, RO, ES, SK, UK
Not peak	AT, BE, HR, CZ, DK, EE, FI, FR, DE, EL, HU, IE, IT, LV, LT, NL, PT, RO, ES, SK, UK
More time of use	CZ, DK, FI, IE, IT, LU, NL, ES, SE, UK
Critical peak	FR
Real time	AT, BE, EE, FI, DE, NL

The types of tariffs adopted for demand response are:

- Seasonal: rates vary according to the season
- Peak: Rates vary depending on the times and days when demand is usually high
- Off-peak: Rates vary depending on the times and days when demand is usually low
- Other time of use: the rates vary according to the times and days when the demand is usually medium
- Critical Peak: Rates vary in order to lower peak demand

- Real time: rates vary in real time following the hourly market price

2.4 Italian situation

The concept of "load management" has seen its spread in Italy since the seventies. In fact , in the 1970s interrupted load programs were adopted as a solution to critical events linked to insufficient generation capacity. Over the decades, those programs have gradually lost importance, however as the new millennium began, this program has regained importance.

Very important in the field of **Demand response** was the introduction of the first Time of Use tariffs which, as already mentioned, the price varies according to the price of the wholesale market. The first Time of Use tariffs in Italy were introduced in the 1980s for high voltage customers and subsequently for low voltage customers [26].

As for the **energy efficiency line** on homes, the process began after the energy crisis of the 1970s, in response to this energy crisis, Law No. 373/76 was approved which concerned the containment of consumption for heating buildings. .

Another important step was taken by the evolution of the law n.373 / 76 just mentioned, that is the **Law n. 10/91** [27] (and subsequent modification) which established, according to the criteria indicated by the energy saving policy drawn up by the European Economic Community, the rules for the implementation of the National Plan for the rational use of energy and the development of renewable energy sources. This represents the first law that governed the design and management methods of the building / plant system, with the aim of guaranteeing energy saving, environmental sustainability and the comfort of the building occupants. This rule also obliges the client to submit to the Municipality the technical report drawn up by the responsible engineer to certify compliance with the requirements. Finally, another important aspect introduced by law 10/91 was the figure of the “person responsible for the conservation and rational use of energy” who represented the figure of the Energy Manager himself.[9]

Subsequently, there have been several successive legislative acts drawn up by the competent authorities. The most important legislative act of recent years is **Law 90/2013** [28] with which Italy transposed the European Directive 2010/31 / EU on the energy performance of buildings. It included the definition of the concept of nearly zero energy buildings (NZEB) and replaced the old certificates with the new Energy Performance Certificate (APE). The legislative act was then implemented with the **Ministerial Decree of 26/06/2015** [29] which consists of three distinct decrees:

- The first concerns the methodologies for calculating the energy performance of buildings and the definition of the minimum requirements.
- The second, which defined the requirements to be followed for the preparation of the technical report for the various cases of new construction and renovation of the building or technical systems.
- The third, which defined the national requirements for the Italian energy certificate, the APE.

The calculation method indicated by the provisions of the decree, used to evaluate the energy performance of buildings, is mainly represented by the UNI 11300 series. It is important to note that those series of standards are based on the international and European standard EN ISO 13790 which presents a calculation method recently replaced by the standard EN ISO 52016 [c45] The latter has been approved by the Italian standardization authority UNI; therefore, the requirements for calculating the energy performance of buildings may change in the future.

Another important piece of legislation relating to energy efficiency is **Legislative Decree 102/2014** [46]which transposed the European Directive 2012/27 / EU, whose requirements can be summarized as follows:

- It has set the national target for energy saving;
- Established the mechanism of White Certificates, which was to provide an important contribution in the pursuit of the energy saving objective;
- Sets the mandatory nature of the energy audit for large industrial buildings;
- Sets the introduction of effective metering systems and thermostatic valves in buildings;
- Introduced the concept of Energy Performance Certificate (EPC) and prepared the certification for Energy Service Companies (ESCO), according to the UNI CEI 11352 standard;
- Introduced the provision for the enhancement of energy efficiency, renewable sources, distributed generation and the active participation of demand in the energy system. The Ministry, in fact, has instructed the authority to develop, in collaboration with the TSO, the methods for allowing consumers to participate in network services, even in aggregate form.

As mentioned in the previous paragraph, Italy is not among the virtuous countries in the development of **Demand Response solutions** . However , in recent years Italy has adopted some reforms of the Clean Energy Package and realizing that it will be difficult to respond to the new energy crisis, in my opinion Italy could soon improve its position on the Demand Response it will bring and therefore become one of the virtuous countries within a few years.

2.4.1 Interruptible loads in Italy

Before 2017, Interrupted Loads were the only service present in the Italian system attributable to the DSM.

Observing the scheduled period 2018-2020, the amount of interruptible load available is 3,900 MW. This service has remained independent from the Balancing Market; in fact, it is used only when the power produced is not sufficient to maintain the operational safety of the system.

To participate in this type of program, users must meet two main requirements:

- Minimum capacity of 1 MW
- Ensure user logout in two available modes:
    1. In real time, with an activation time of less than 200msec following a remote signal sent by the Transmission System Operaton .
    2. In deferred time, in emergency conditions with activation time of less than 5 sec following a remote signal from the Transmission System Operaton

In my opinion, this interruptible load could be expanded by accenting customers with an operating capacity of less than 1MW, but now it is only possible for large plants.

2.4.2 Italian market for auxiliary services

One of the most important interventions for demand response is represented by the MSD dispatching market procedure.

Energy dispatching is the activity of managing and balancing the flows of electricity through the transmission grid and serves to ensure a correct balance between supply and demand. A fundamental function, given that electricity cannot be stored and consequently must be produced and consumed continuously. Furthermore , the energy, which must be sufficient to meet the demand, must be transmitted through the national electricity grid. In our country, energy dispatching is entrusted to Terna, a listed company that performs a fundamental public service and deals with all operations for the safe management of the national transmission grid

Terna guarantees the constant balance between the energy that is produced in the various plants and that which is consumed by end users. To meet the country's energy needs at all times, Terna adopts various strategies. The Dispatching Service Market (MSD) is the tool through which Terna SpA procures the resources necessary for the management and control of the system (for example, the resolution of congestion and the balancing of the Grid). On the MSD managed by the Electricity

Market Manager (GME), Terna acts as a central counterpart: prices in this market can reach high peaks, since the service that must be guaranteed by producers is instantaneous.

At times when the demand for energy increases significantly, Terna can also ask some producers, usually of significant size, to consume less energy. This is the so-called interruptibility service to which large energy producers adhere, for a fee.

Lastly, Terna has the possibility of concluding service contracts with some energy production plants, without contacting the MSD market. In some cases, the intervention of these plants can be indispensable because it helps to maintain a certain frequency of energy in an area or to guarantee the margins of caution necessary to avoid blackouts.

The energy dispatching service is therefore of particular importance, since if the balance between supply and demand is not maintained, the system goes into blackout. An issue that has become even more complex since production from renewable sources, which produce energy in a non-programmable way, is increasing in Italy.[10]

2.4.3 Retail market and tariff schemes

As already highlighted above, Italy is not one of the countries in the management of Demand Response . Today the Italian market can be divided into three types of service that the consumer can choose:

- **“Mercato tutelato”** , which includes customers, domestic or small low voltage businesses, who do not participate in the free market and are subject to fixed prices established by the ARERA body. In this case, the price of energy is divided into: Expenditure on energy, expenses for transport and management of the meter, expenses for system charges and taxes. Each expense varies proportionally with the consumption made. The cost of the various expenses remains varied every three months.
- **“Libero mercato”** which provides for more variable prices that are set directly by retailers following the energy market. The characteristic of this market is that the seller can propose a fixed price of energy even for 24 months and after the end of the contract he is free to change the price of energy independently.
- **“Salvaguardia”** , which represents a “mercato tutelato” for customers who do not have a contract on the free market and cannot access the Major Protection Service, therefore medium voltage users or medium-large low voltage companies.

In general, it is possible to identify three different types of tariffs that the consumer can choose:

- Flat rate: with a fixed electricity price during the day, independent of the time of energy consumption . This tariff can be adopted either in most protection or free market.
- Double tariff: peak / off peak tariff that differentiates two different prices according to the moment in which the energy is consumed. This type of tariff can be adopted by both greater protection and free market and distinguishes:
    - High price level: F1 price range. (Mon - Fri , 8: 00-19: 00);
    - Low price level: price ranges F2 (Mon - Fri , from 19:00 to 8:00) and F3 (weekends and holidays), often indicated on the bill as F23.
- Multi-hour rate: which includes three different price ranges that depend on both the time of day and the day of the week. It can only be adopted by non-domestic users for most of the protection service or by all customers in the free market and distinguishes the following price ranges :
    - Peak time slot (F1): with high price level (Mon - Fri , 8: 00-19: 00);
    - Intermediate time slot (F2): with average price level (Mon - Fri , 7: 00-8: 00 and 19: 00-23: 00 or Sat , 7-23);
    - Off-peak hours (F3): with lower price range (Mon - Sat , 11 pm-7am, Sundays and holidays).

Therefore, the Italian state of development is not one of the most advanced in the European framework, however the growing attention of the Government, authorities and market players leads to a deepening of the subject. Considering the current situation and the indications contained in the new regulations and directives of the European Union, it is possible to hypothesize a future and not so strong growth of the sector both from a market and a technical point of view.[9]

2.5 European situation change due to the Russia-Ukraine war

The European energy situation will undergo many changes due to the conflict with Russia. In fact , on May 18th the European Commission presented the REPowerEu energy plan . The goal is to give up Russian gas by 2030 (possibly by 2027). This quantity corresponds to about 155 billion cubic meters every year Europe imports from Russia, thus corresponding to 45% of total natural gas [4],

[18]. The impact on the European energy situation will be very strong , especially according to which a reduction of third parties is expected by 2022.

The way in which Europe plans to support the reduction of natural gas is based on three sources:

- Energy saving
- Diversification of sources
- Development and introduction of renewable energy

We know this plan very well as the Paris agreements already follow this plan, however, due to the geopolitical crisis, the plans towards the European Green Deal provide for a further push.

This push means that in 2030 around 80% of the [4]electricity will have to be produced from renewable sources. The main problem with this scenario is that such a development has never been considered by 2030, but it was intended to be there by 2040.[19]

According to Eurostat data, in Europe in 2020 over 70% of primary energy came from fossil fuels, renewable energy only 17.5% while nuclear 12.5%.

The plans to produce such a large amount of energy from renewable sources require the installation of 45 GW of photovoltaics every year in order to install 600 GW by 2030 or quadruple the energy produced. This expansion of solar energy has already been discussed in the DG scenario of the European Union . Unfortunately

2.6 REPowerEU

In response to the energy difficulties caused by the world energy market heavily dependent on the overrun russia in ukraine, the european commission presented the REPowerEU plan ,

This plan is mainly based on three principles :

- Saving energy: The energy saving plan is not yet well organized, at this moment the media will try to influence the population for energy saving, unofficially the reduction in energy demand is driven by the imbalance between supply and demand that is leading to an increase in energy prices which leads to a decrease in energy demand. In addition, in the states of the European Union are improving the emergency measures in case of supply interruption
- Producing clean energy: Investing in renewables means becoming energy independent. In addition, we can say with good approximation that in Europe renewable energies are the cheapest energy available to be produced internally. To confirm this, in these period (from

March 2022 to June 2022) we are noticing that the price of electricity is no longer driven by the marginal price of renewables but by the marginal price of methane. So we can deduce that the most expensive energy source in the European energy mix is methane.

- Diversifying our energy supply: The European Union is collaborating with several international partnerships to find alternative energy supplies. In the short term, we will need standard energy supplies such as natural gas, oil and coal. In the future, it is planned to add hydrogen to the energy mix.

2.7 Energy dependence on Russia

The new geopolitical reality is leading the European market to accelerate the energy transition towards clean energy and drastically decrease the dependence on energy supply from suppliers deemed unreliable.

With REPowerEU , therefore, the European Commission's plan to make Europe independent from Russia well before 2030 is implemented. The problem is that today energy dependence is not possible as we depend on energy from non-European countries for energy. Indeed , as show in Table 2-2 Europe imports around 23,000,000 TJ of crude oil from European countries, producing only 2 900,000 TJ and exporting only 1 900 000 TJ. Dependence on Russia is enormous as 29% of extra-European crude oil comes from there. This means that about 25% of the crude oil consumed in Europe comes from Russia. For other energy sources the situation is similar. In fact , the total amount of natural gas imported into Europe is 18,600,000 TJ, total production is about 4,000,000 TJ while exports are about 3,000,000. 43% of extra-European gas comes from Russia. So it means that 35% of the gas consumed in Europe is Russian. When it comes to coal, imports have been steadily decreasing for decades. In 2019, extra-European coal was around 3 800 000 TJ, export of around 500 000 TJ and production of 4 200 000 TJ. Of the extra-European imports, 54% comes from Russia, so the Russian coal used in Europe is about 2,000,000 TJ, corresponding to 26% of the total.[20][11]

Table 2-2 Russia's fossil fuel addiction in Europe in 2019

2019	Total Import (TJ)	Total export (TJ)	Production (TJ)	Russia import (TJ)	Russia import / Total Import	Russia import / (Total import + Production)
Oil	23000000	1900000	2900000	6670000	29%	26%
Natural Gas	18600000	3000000	4000000	7998000	43%	35%
Coal	3800000	500000	4200000	2052000	54%	26%

Given Europe's great energy dependence on Russia, various precautionary measures are currently being implemented to reduce its dependence.

The measures that will be taken are divided into **short-term measures** and **medium-term measures** which will be described in the following paragraphs

2.8 REPower: European short-term measures

Short-term measures are all those measures that must be taken in the present time and within one year of the decision.

These measures therefore include:

- Joint purchases of gas, LNG and hydrogen via the EU Energy Platform. They also want to participate in this platform because of Europe but not within the European Union such as Ukraine, Moldova, Georgia and the Western Balkans.
- more reliable energy suppliers and implement future cooperation for the production of renewable and low-carbon gases.
- A rapid realization of projects in the solar and wind energy sector combined with the diffusion of hydrogen produced from renewable sources. This is to decrease imports of methane gas.
- Increase in Biomethane production to reduce methane imports.
- Approval of EU hydrogen projects by summer 2022
- Bring gas storage to at least 80% of capacity before the winter period begins, therefore by November 1, 2022
- Demand reduction plans coordinated at European Union level in the event of gas supplies

These short-term measures are in my opinion too much ambition to be implemented as many measures are based on experimental measures which are still in full competition with each other. For example, the production, storage and uses of hydrogen still present a big problem from an engineering point of view as to date this source does not present economic competitive levels to enter the national energy mix. A similar argument applies to the production of biomethane as in the short term it would be difficult to think that it can enter the European national energy mix as it was designed to be produced as storage in times when the production of electricity produced from renewable sources exceeds the question. However, as shown by the DSM study, this scenario is still a long way off.

2.9 REPower : European medium-term measures

The European medium-term measures that will be described aim to be completed by 2027.

These measures are measures to avoid a European recession and to continue the plan for energy independence. For now, these medium-term plans are not specific but give guidelines to follow. Medium-term measures are plans that seek as much as possible to be sustainable at the same time from an economic, social and environmental point of view. In fact, it provides:

- REPowerEU plans in the framework of recovery and resilience with a total of investments and reforms worth € 300 billion
- Strengthening of industrial decarbonisation with 3 billion euros from the European fund for innovation
- New rules and recommendations to speed up the bureaucracy in the renewables sector. Measures that focus more on areas with a low environmental risk
- Investments in the gas and electricity network to ensure greater flexibility of demand
- Increased ambition in energy saving with the raising of the European Union's efficiency target from 9 to 13% by 2030
- Increase once again from 40% to 45% of the European target for renewable energy by 2030. In other words, that in 2030 the energy mix
- New proposals from the European Union to guarantee industry access to critical raw materials in order to avoid a decrease in production
- An accelerator in the field of hydrogen to obtain 17.5 GW of electrolysers by 2025 to power the EU industry with an internal production of 10 million tons of renewable hydrogen
- A modern and up-to-date regulatory framework for hydrogen

These are the official points published on EC.Europa.eu, in my opinion they are too ambitious measures to be implemented in the medium term. Taking as an example the increase to 45% for renewable energy by 2030. It turns out to be very difficult as already to reach 40% by 2030 the energy mix expected to reach 40% renewable energy in the heating and cooling, 20% renewable energy in the transport sector and 60% in the electricity sector [3].

Now that this target has been raised to 45% the situation seems even more extreme with renewable energy in the electricity mix than at 80% [4]. From the DSM point of view, raising renewable energy in the energy mix to 80% raises many energy management problems that in the past it was not possible to solve them so quickly.

3. Study of the energy situation

This chapter deals with studying the trend of energy over time. Chapter includes four paragraphs, in the first paragraph the Italian situation was analyzed, in the second the situation in the city of Turin and in the third and fourth paragraphs there is a brief mention of the world and European analysis.

3.1 Italian energy situation

This paragraph analyzes energy management in Italy. This study starts from a trend in primary energy demand over time and then passes specifically with the production of electricity by studying seasonal and daily trends. The chapter subsequently hypothesizes future scenarios for the production of electricity based on the policies described in the previous chapter.

To appreciate the improvements in energy efficiency in Italy, it is necessary to study the trend of primary energy from 1990 to today. In fact, as shown in the figure3-1 [11], we can see that both liquid and solid fuels have decreased their consumption, similarly as shown in the figure, the production of CO2 has also decreased.

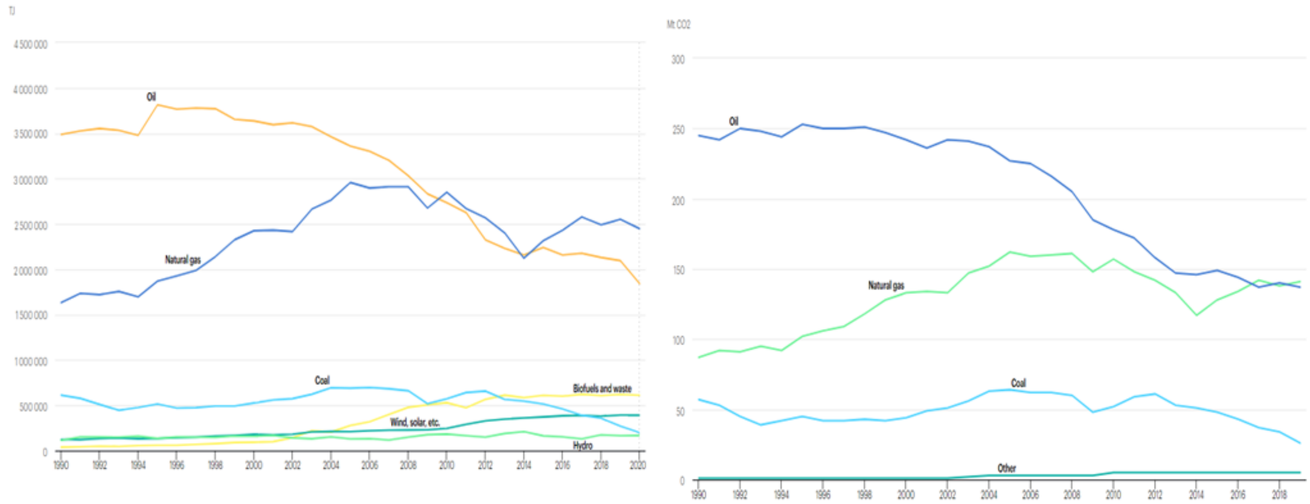


Figure 3-1 Trend of the energy supplied and of the pollution produced by the Italian energy mix

Specifically, we note that from the point of view of pollution, CO2 emissions have decreased by 30% from the all-time high reached in Italy (in 2005), emissions have had a big drop as since 2005 there has been a fall in use of liquid and solid fuels. This drop in CO2 production by liquid and solid fuels is due to three main reasons:

- Replacement of liquid fuel heating boilers with natural gas boilers
- The increase in efficiency in thermal, electro-thermal power plants and in transport
- The increase of renewable sources

The replacement of liquid fuel heating boilers took place thanks to the enlargement of the methane gas pipeline. This allowed consumers to improve and lower the costs of the heating service, in addition to and closely linked to the increase in energy efficiency as the new boilers offered a qualitative leap over the old ones.

The increase in efficiency that saw the start of higher efficiency thermoelectric plants, all is due to several factors, the first of all being the prices of fossil fuels as since the 2000s there has been a gradual rise in prices until reaching the maximum in 2005 as shown in the Figure 3-2 and Figure 3-3[12]

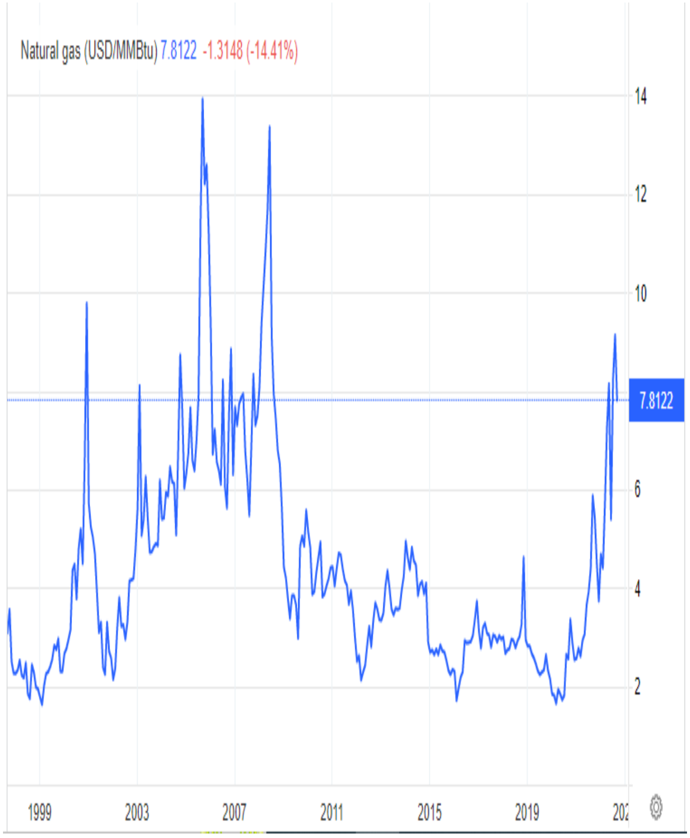


Figure 3-3 Gas price trend

Figure 3-2 Oil price trend

Over time, the increase in the cost of energy, the awareness of the pollution generated, has generated over time increasingly restrictive policies on pollution. Consequently, in Italy they have found fertile ground to grow renewable sources. As shown in the figure, the main renewable energies are:

hydroelectric, wind, solar and biofuels which, as we will see in the course of the report, will all play an important role in DSM's strategies.

3.1.1 Electrical Situation

As for the electrical situation, the annual consumption is around 290TWh. The largest contribution to energy production comes from natural gas alone covering about 48% of total energy while the other major contribution of energy is given by renewable sources about 40%. The most important forms of renewable energy are: hydroelectric, photovoltaic, wind and biofuels. The table 3-1 and figure summarize numerically and graphically the energy sources used to form the 2021 national electricity mix,

Table 3-1 National electric mix

Energy sorse	TWh
Natural gas	137.649
Hydro	48.558
Solar PV	24.942
Wind	18.702
Biofuels	17.33
Coal	13.064
Oil	9.771
Geothermal	6.029
Waste	4.838
Municipal Waste	4,768
Waste (renewable)	2.384
Other sources	0.604
Total	288.639
Renewable	117.945

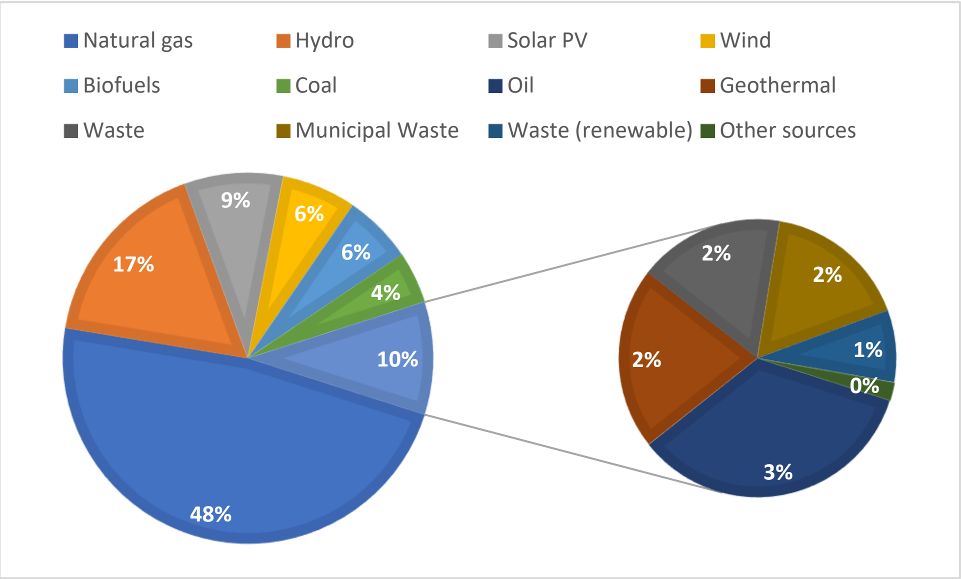


Figure 3-4 National electric mix

As already described in the previous chapters, renewable energy sources often have the disadvantage that they are not always available during the day and their availability also varies during the months of the year.

The figure 3-5 end the Table 3-2 shows the production of electricity from renewable sources month by month during the year 2021

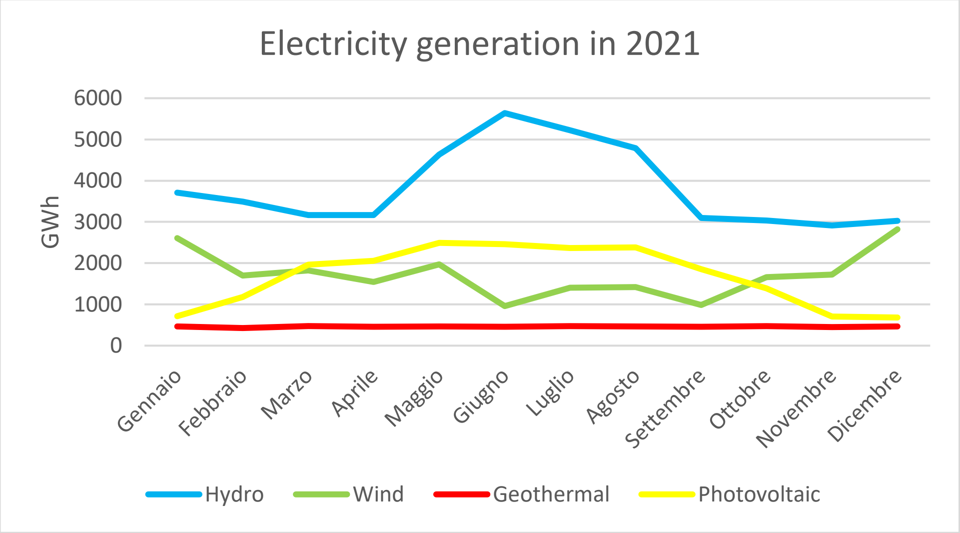


Figure 3-5 Generation of electricity from renewable sources in 2021

Table 3-2 Generation of electricity in 2021

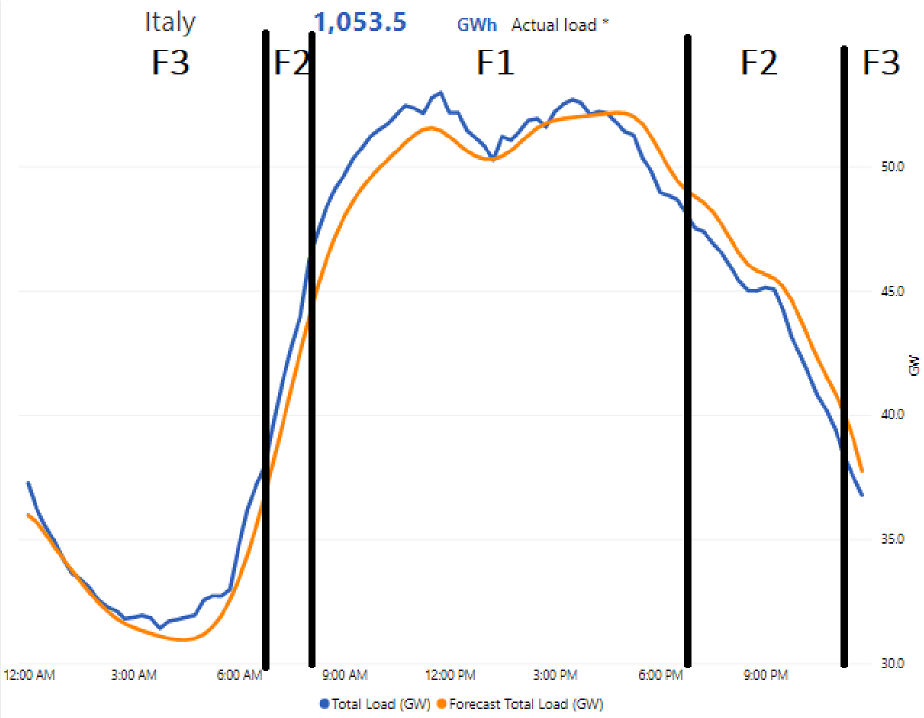
2021	January	February	March	April	May	June	July	August	September	October	November	December
Thermal	14105	11549	12459	12028	9303	11861	14023	11761	14122	13310	16496	16207
Net Foreign Exchange	3356	4403	4265	2878	3448	3540	4386	3718	4117	4231	2172	2274
Hydro	3711	3490	3163	3167	4632	5640	5221	4792	3094	3036	2915	3029
Self-consumption	2303	2310	2507	2066	2364	2463	2679	2317	2578	2478	2328	2233
Wind	2604	1697	1826	1541	1968	959	1404	1424	984	1664	1719	2822
Geothermal	465	427	475	459	465	455	470	463	458	472	448	468
Photovoltaic	715	1181	1965	2056	2493	2458	2366	2381	1857	1392	710	682
Pumping-Consumption	-193	-249	-239	-264	-284	-190	-144	-206	-217	-213	-308	-319
Total Energy	27065	24809	26420	23931	24390	27188	30404	26650	26994	26370	26480	27397

It can be seen from the figure 3-5 that hydroelectric and solar energy are more available in the summer seasons while wind energy is more available in the winter seasons. While geothermal energy which is constant throughout the year represents an energy source too small to be compared with the others.

According to the analyzes made by the backhoe loader, hydroelectric and geothermal energy have reached their maximum, while a substantial increase in energy is expected due to photovoltaics and wind.[13]

Specifically in the current demand, we note that solar energy is strongly present in the warm seasons but very little present in the cold seasons, showing seasonal average points around the spring and autumn solstices. Mind regarding wind energy we note that it is present in all seasons with a peak in the winter season and presents a certain unpredictability .

As for the demand in Italy we can see as shown in figure 3-6 [14]that the loads have 2 peaks respectively at 11.00 am and 4.00 pm . As mentioned in the previous paragraph , in Italy as in Europe, the use of DSM strategies was encouraged by dividing the day of a day into 3 time slots. For several years now, depending on the time slot, in fact , the price of electricity has been dependent, going from the more expensive F1 to the cheaper F3 . This division aims to reduce as much as possible the energy peaks within the day and to move a part of the electrical load in the time slots where energy is less required as most of the production plants have difficulty generating. Powers lower than nominal powers and as they suffer in the switching on and off phase of the control unit. This division was initiated in 2005 * and kept on a large scale to this day; however, today there is a greater variance of energy sources, mainly due to the increase in renewable energy.



* The value doesn't take into account the quarterly data exceeding the complete hour

Figure 3-6 Request and supply of electricity

most important renewable energy source after hydroelectricity is photovoltaic energy. This energy source does not need fuel, but only very low maintenance. The energy produced by photovoltaics has a price that competes with fossil sources, plus it is produced in the hours of maximum demand (in the F1 time slot). This energy source, due to its characteristics, changes the balance of supply and demand.

The following figure 3-7 [14] show the hourly energy balance for various sources, while the figure shows the energy balance excluding solar energy to highlight the change in the current time bands.

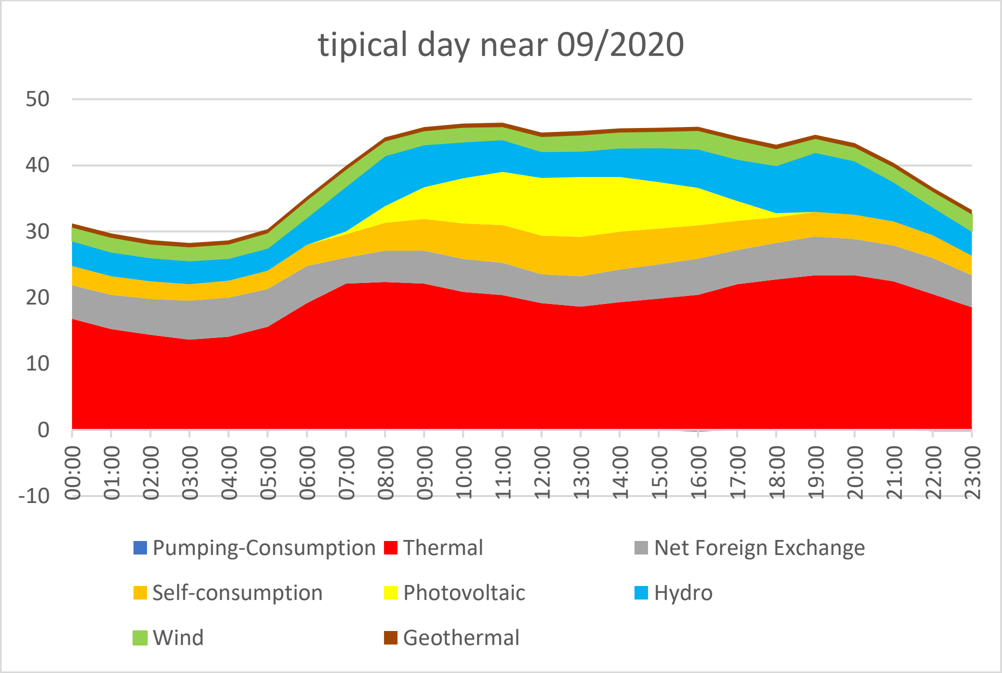


Figure 3-7 Energetic mix on a typical September day

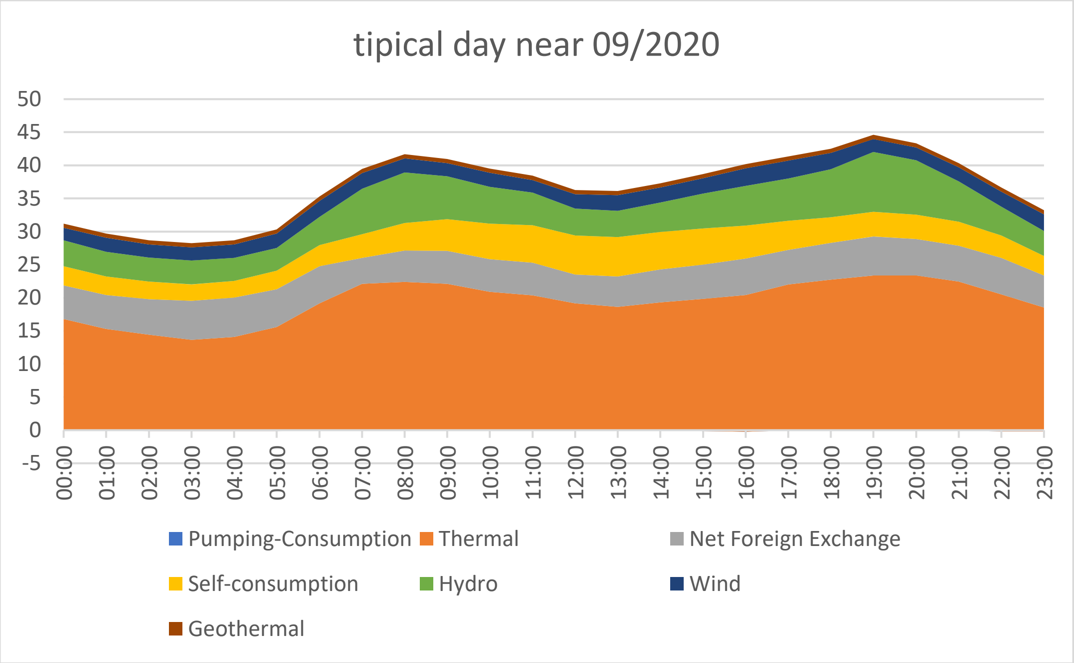


Figure 3-8 Energy mix on a typical day in September by removing solar production

As shown in the figure 3-8, if we study the energy peak excluding solar energy, we note that the time bands F1, F2 and F3 which historically have always been a function of energy demand, now no longer represent the cost trend. therefore a different distribution of the time bands is assumed in future periods since, as we will see in the next chapter, an increase in the influence of solar energy is expected.

To complete the study, with reference to the figure 3-9 and 3-10, the relative situation of the winter and summer substitution period during working days should be shown [14].

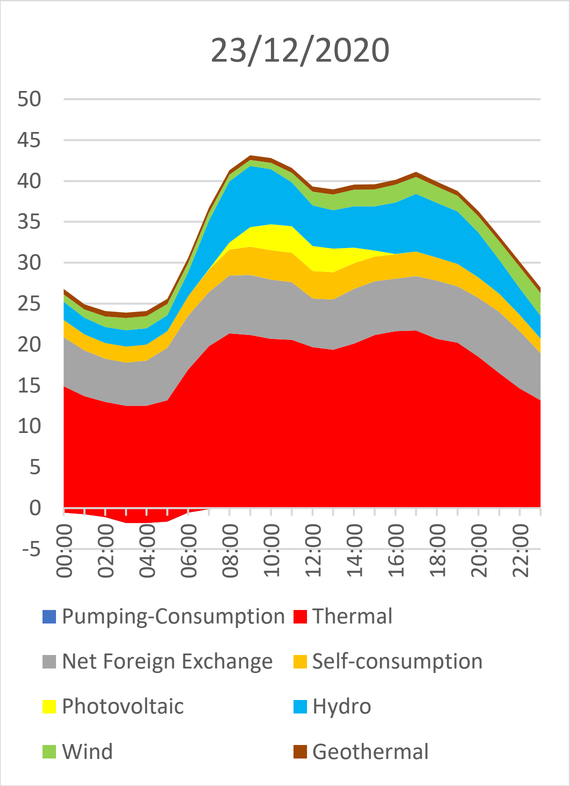


Figure 3-10 Energy mix on Winter Solstice

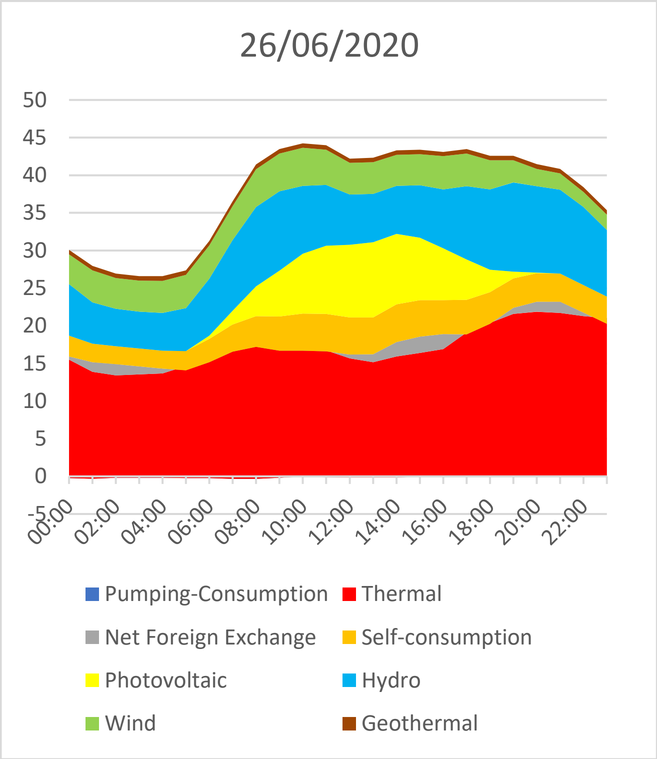


Figure 3-9 Energy mix on Summer Solstice

As shown by the those figure, the presence of photovoltaics in fact the only time of the year where electricity imports from abroad are eliminated is precisely the summer season, as although taking into account that due to the cooling of buildings the demand for energy summer electricity is higher than in other seasons, photovoltaic production not only completely holds up the surplus given by cooling but exceeds it by eliminating the electricity purchased from foreign imports and decreasing the energy generated by phosil fuels as shown in the table 3-3, Infact the table 3-3 compares the energy mix for the three reference seasons

Table 3-3 Comparison of the electric mix in the seasons

	Energy balance 21/09/2020 (GWh)	Energy balance 21/06/2020 (GWh)	Energy balance 21/12/2020 (GWh)
Pumping-Consumption	1-1.56	-2.95	-8.76
Thermal	468.75	421.23	436.4
Net Foreign Exchange	124.76	7.2	155.93
Self- consumption	96.511	91.876	63.708
Photovoltaic	64.93	82.75	18.35
Hydro	126.37	196.51	110.39
Wind	52.75	94.38	38.66
Geothermal	15.38	14.63	14.87
Total	947.891	905.626	829.548

3.1.2 Italian demand forecasts

The study conducted in this report reports the forecast of future electricity demand by comparing it with current electricity demand. This study is based on predicted scenarios of the energy transition predicted by tern [13] .

According to the study conducted by terna, the possible scenarios are:

- **Sustainable scenario Transition (ST)** sees a rapid and economically sustainable reduction of CO2 emissions by replacing coal and lignite in electricity generation with gas. The use of gas also partially replaces the use of liquid fuels in some sectors such as heavy transport. The electrification of heating and transport is proceeding more slowly than in the other scenarios for the achievement of the European CO2 reduction targets;
- **The Distributed Generation (DG) scenario** presents a development vision of the decentralized electricity system with a focus on the evolution of technologies to support end consumers. The latter play a central proactive role and electric vehicles have a high market

penetration as well as photovoltaic installations and batteries in buildings. These developments involve high levels of Demand Response ;

- **The Global Climate Action (GCA)** is the scenario that requires the greatest effort towards decarbonisation. Great emphasis is placed on the development of renewable and nuclear power plants in the electricity sector. The electrification of heating in the residential and tertiary sectors leads to a gradual decline in the demand for gas in these sectors. The decarbonisation of transport is achieved through the growth of electric and gas vehicles. Energy efficiency measures affect all economic sectors.

In 2030 the GCA scenario was replaced by a complementary storyline **(EUCO 30)** modeled and prepared by a consortium led by E3Mlab and hosted at the National Technical University of Athens (NTUA), with the collaboration of the International Institute for Applied System Analysis (IIASA). In particular, the scenario illustrates the achievement of the climate and energy targets set for 2030 by the European Council in 2014 and includes energy efficiency equal to 30%.

The following figure 3-11 shows the development of the scenarios just mentioned with a comparison with 2020. The forecast goes from 2025 to 2040.

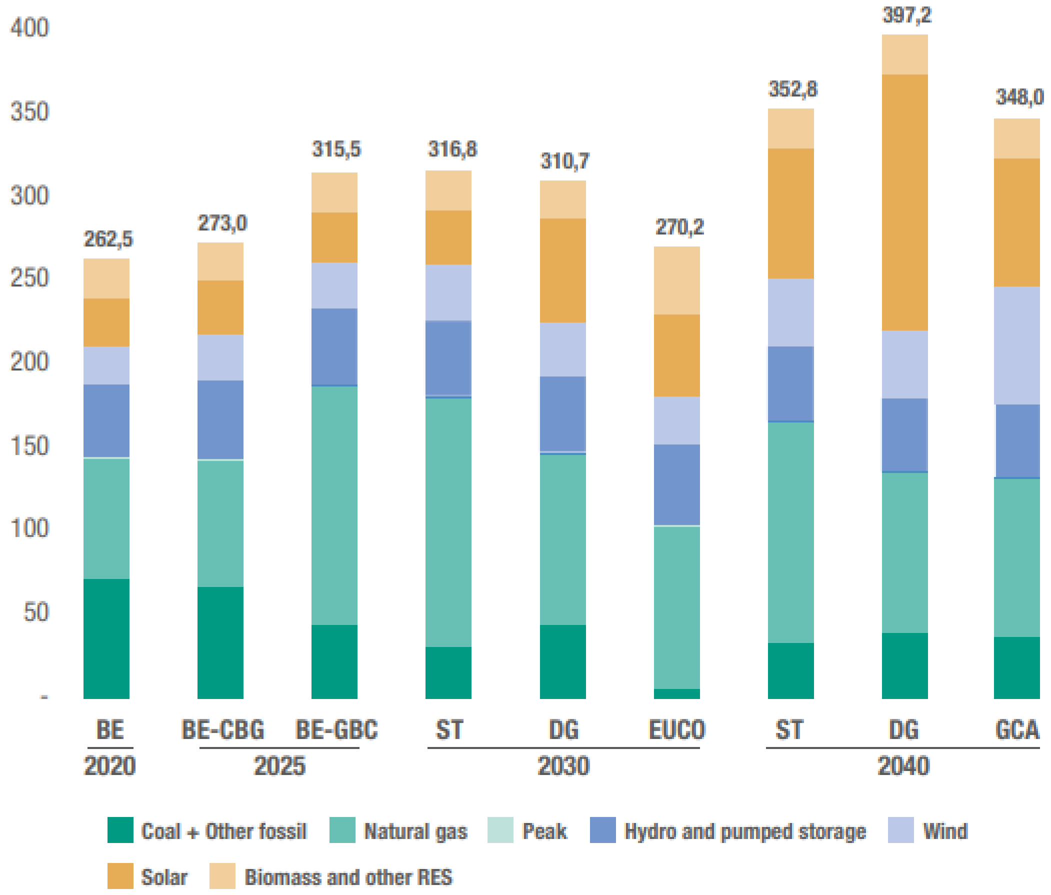


Figure 3-11 Comparison of the electricity mix in Italy in 2020 with 2025, 2030, 2040 in TWh

To go forward with the report, it was decided to follow the GCA scenario which therefore correspond to the EUCO 2030 and GCA 2040 scenarios.

The following table 3-4 analyzes the chosen scenarios quantitatively.

Table 3-4 Comparison of the electricity mix in Italy in 2020 with, 2030 and 2040

	Energy balace 2020 (TWh)	EUCO Energy balace 2030 (TWh)		GCA Energy balace 2040 (TWh)	
Thermal	156	94	-40%	127	-19%
Bio energy	17	35	+ 106%	22	+ 29%
Net Foreign Exchange	33	33	+ 0%	33	+ 0%
Hydro	48	48	+ 0%	48	+ 0%
Wind	18.7	25	+ 34%	67	+ 258%
Geothermal	5.5	5.5	+ 0%	5.5	+ 0%
Photovoltaic	24	57	+ 138%	82	+ 242%
Total	262.5	270.2	+ 3%	348	+ 33%

It is very important to observe the meaning of the scenarios. In fact , in the face of an almost constant demand until 2030, the penetration of renewables changes further. In particular , we note the photovoltaic production which sees an increase compared to 2020 of 138% in 2030 and 242% in 2040, wind energy instead sees an increase compared to 2020 of 34% in 2030 and 258% in 2040, this An increase in renewable energy leads to a decrease in fossil fuel sources which see a decrease compared to 2020 by 40% in 2030 and 19% in 2040.

3.1.3 Future Italian Electrical Situation

Constructed energy demand is based on current demand trends, while paying attention to the energy transition. The trend of future energy demand will therefore be proportionally equal to the current hourly trend multiplied by a constant given by the ratio between the future average annual energy hypothesized by the triad on the average annual energy of 2020 for that particular energy source.

Then the new demand curve for each source will be calculated as:

$$Dh_{sorsei\ yearj} = Dh_{sorsei\ yearj} \cdot \frac{Dy_{sorsei\ yearj}}{Dy_{sorsei\ yearj}}$$

- Dhsorsei yearj : hourly demand for energy source i in year j
- Dhsorsei yearj 0: hourly demand from energy source i in year j
- Dysorsei yearj : annual demand for energy source i in year j
- Dysorsei yearj : annual demand for energy source i in year j

The biggest flaw of this assumption of demand is that it assumes that in all hours the demand for energy is proportionally the same as in 2020 without taking into account that in the future the energy produced during the day could cost less than that produced at night in the opposite situation. to how it happens now.

3.1.4 Italian Electricity Situation 2030

The annual and hourly energy demand of 2020 for each energy source was taken from Terna's history, while the forecast used is EUCO 2030 generated by Terna.

This construction of this energy demand, therefore, has the defect that supposes a very bad energy flexibility on the supplier side, thus leaving room for the development of flexibility on the demand side.

So taking a typical day of the spring solstice we have:

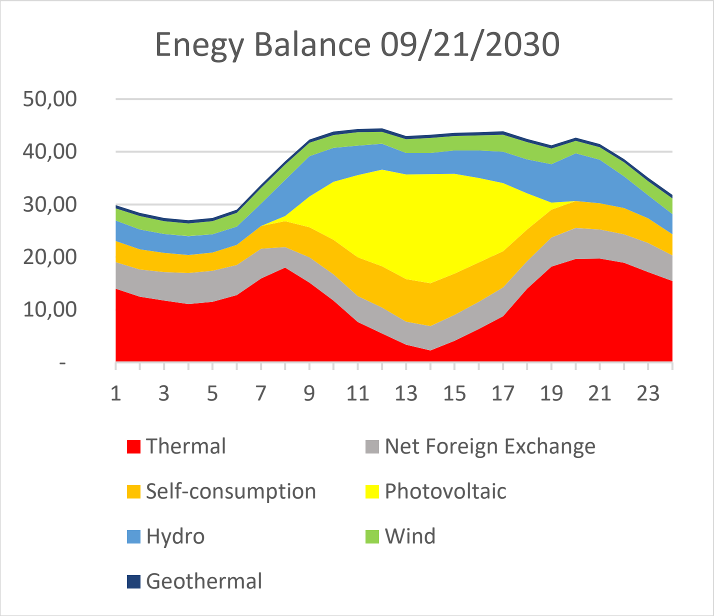


Figure 3-13 Estimated balance of the electricity mix in 21/09/2030

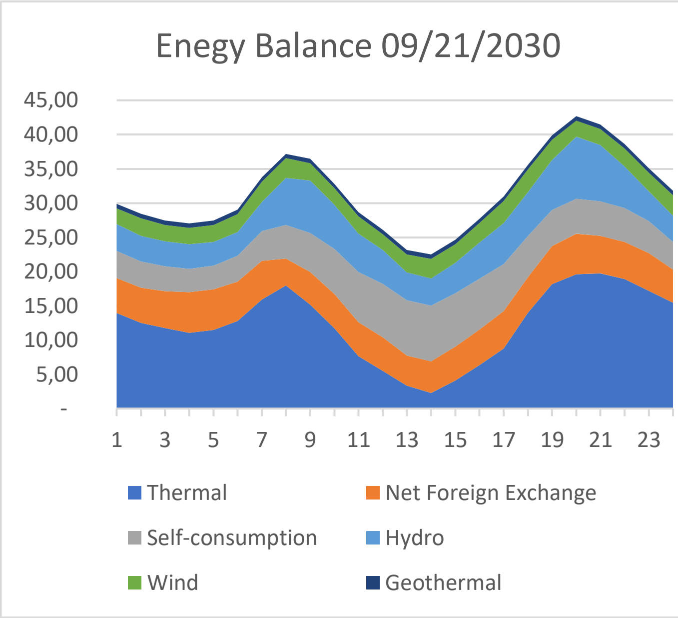


Figure 3-12 Estimated balance of the electricity mix in 21/09/2030 excluding photovoltaic energy

As we can see from the figure 3-13 and 3-14, the historical time bands F1, F2 and F3 have completely changed their meaning compared to 2020 and are completely opposite compared to the distant 2010.

In fact, we see that the hours where energy costs the least is in the F1 range with the minimum peak in the central hours of the day, while the F2 range becomes the most expensive and the F1 region becomes the medium.

Another very important information that comes out is the very low production of electricity from thermal sources in the central hours of the day.

As we know, if the production of electricity brings with it a high production of photovoltaic energy, the electricity mix is expected to change abundantly over the course of the seasons. In fact , the figure shows renewable sources, especially solar, are closely linked to the time of year.

So to have a complete study it must be done for all three opposite solstices:

Winter solstice of 2030 situation is show in the figure 3-14 and 3-15:

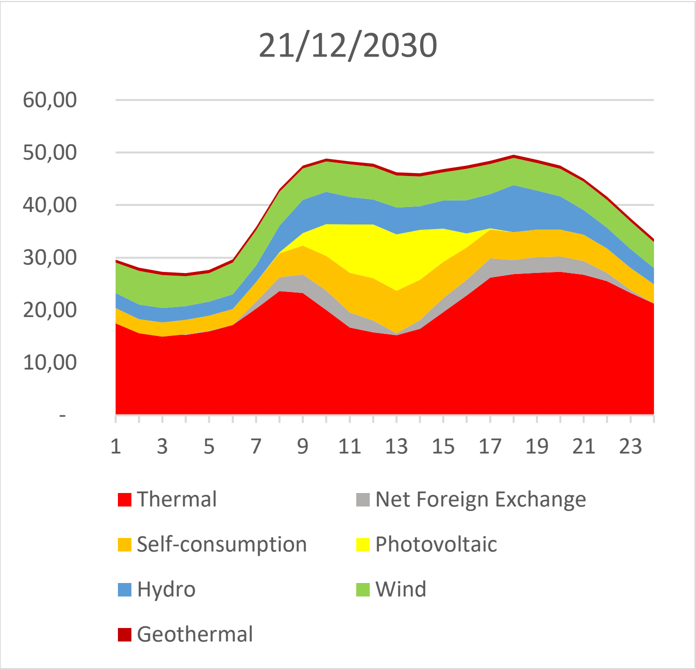


Figure 3-15 Estimated balance of the electricity mix in 21/12/2030

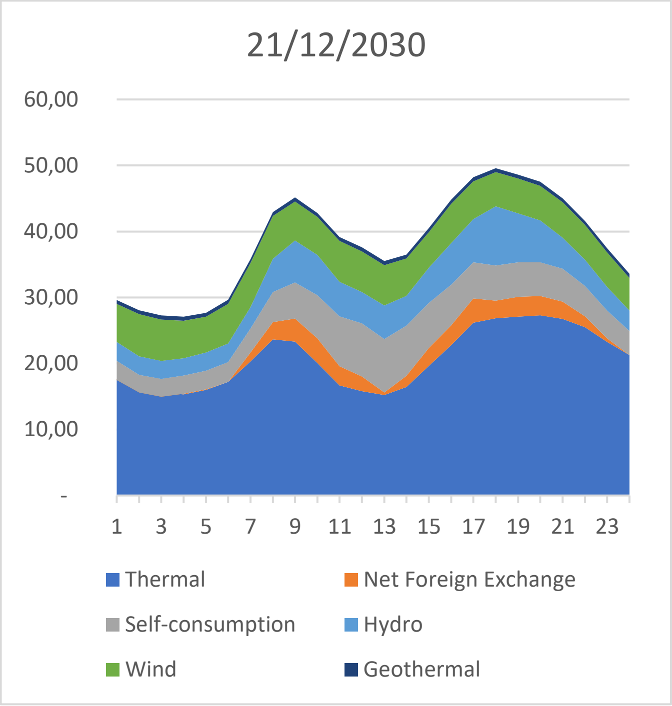


Figure 3-14 Estimated balance of the electricity mix in 12/12/2030 excluding photovoltaic energy

It is noted that the distribution has changed with respect to the situation of the spring substance, the contribution of photovoltaics is much lower, while the contribution from the wind is very high. The F1, F2, and F3 bands are very similar to the 2020 energy mix on a spring day compared to the 2030 electric mix on a spring day.

It is very important to note that to balance the demand during the day in the winter months there will be a lot of contribution from fossil fuels, this information will be very important in the following chapters.

While for the summer substitute is show by figure 3-16 and 3-17:

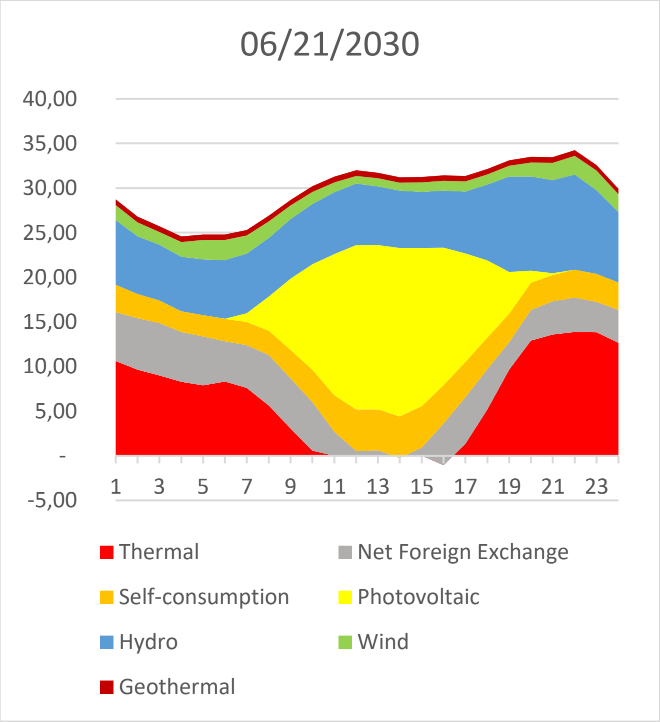


Figure 3-17 Estimated balance of the electricity mix in 21/06/2030

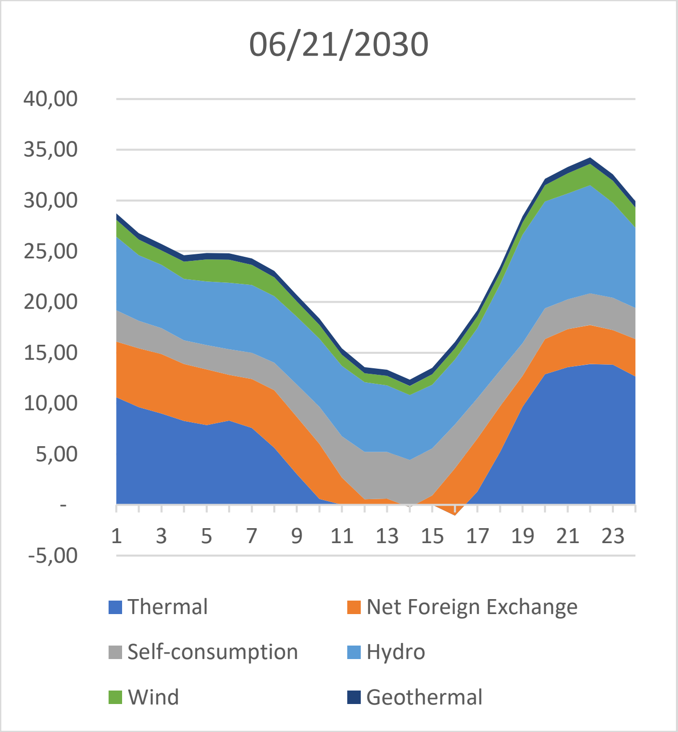


Figure 3-16 Estimated balance of the electricity mix in 21/06/2030 excluding photovoltaic energy

As you can see from the figure, in the central hours of the day , it is expected that renewable sources will satisfy 100% of the energy demand, so there will be a great reduction in imported energy and energy produced by thermal engines. This information will have an important application in the following chapters.

The table 3-5 below makes a comparison between the representatives of typical days in 2030.

Table 3-5 Estimated balance of the electricity mix in 2030

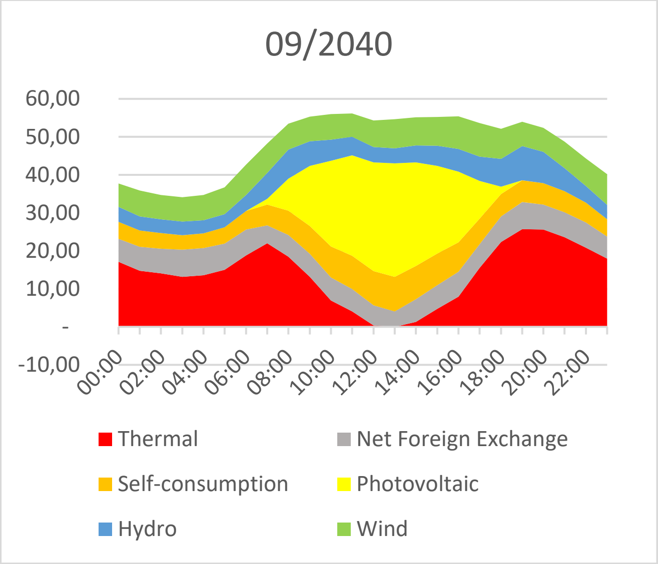
	Energy balance 09/21/2030 (GWh)	Energy balance 06/21/2030 (GWh)		Energy balance 12/21/2030 (GWh)	
Thermal	295.4	152.5	-48%	495.9	+ 68%
Net Foreign Exchange	124.8	94.4	-24%	39.9	-68%
Self- consumption	132.4	80.8	-39%	120.2	-9%
Photovoltaic	148.6	156.4	+ 5%	57.7	-61%
Hydro	126.4	179.9	+ 42%	113.1	-11%
Wind	64	36.8	-43%	138.2	+ 116%
Geothermal	15.4	15	-3%	14.4	-6%
Total	907	715.8	-21%	979.4	+ 8%

3.1.5 Italian electrical situation 2040

The annual and hourly energy demand of 2020 for each energy source was taken from Terna's history, while the forecast used is GCA 2040 generated by Terna.

This construction of this energy demand, therefore, has the defect that supposes a very bad energy flexibility on the supplier side, thus leaving room for the development of flexibility on the demand side.

In the figure there are the typical day of autumn:



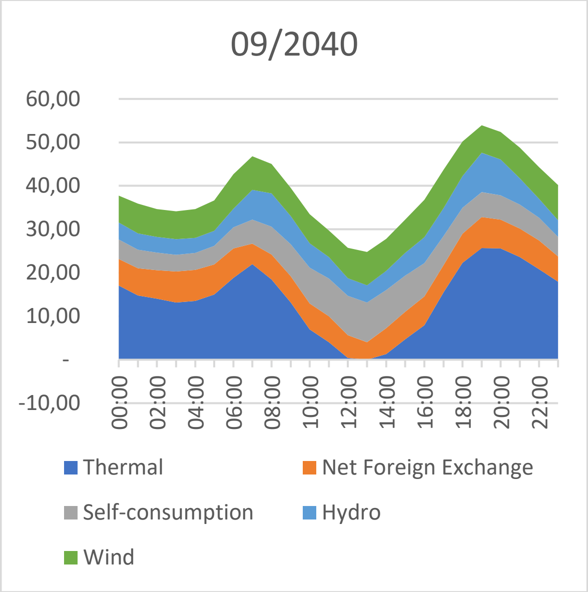


Figure 3-19 Electricity mix in 09/2040 excluding photovoltaic

Figure 3-18 Balance of the electricity mix in 21/09/2040

As we can see from the figure 3-18 and 3-19, the historical time bands F1, F2 and F3 have completely changed their meaning compared to 2020 and are completely opposite compared to the distant 2010.

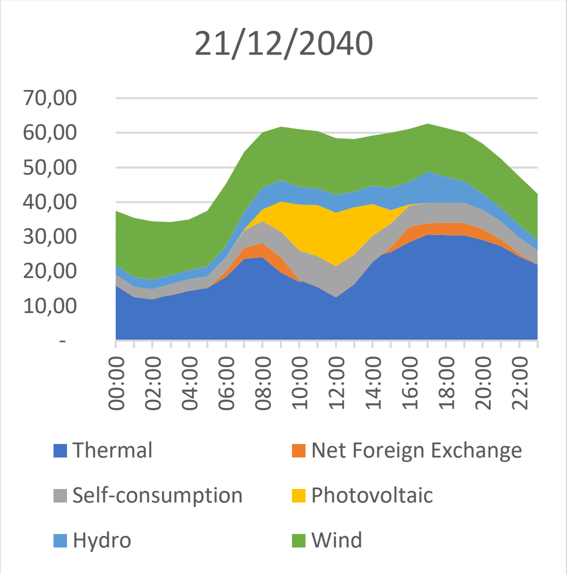
In fact, we see that the hours where energy the least costs (according to figure 3-19) is in the F1 range with the minimum peak in the central hours of the day, while the F2 range becomes the most expensive and the F1 region becomes the medium.

Another very important information that comes out is the very low production of electricity from thermal sources in the central hours of the day.

As we know, if the production of electricity brings with it a high production of photovoltaic energy, the electricity mix is expected to change abundantly over the course of the seasons. In fact , the figure shows renewable sources, especially solar, are closely linked to the time of year.

So to have a complete study it must be done for all three opposite solstices:

Winter solstice of 2040 situation is show in the figure 3-20 and 3-21:



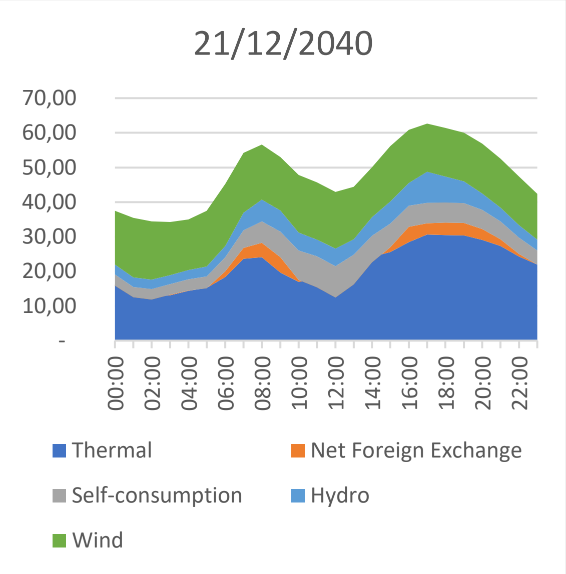


Figure 3-21 balance of the electricity mix in 21/12/2040

Figure 3-20 Balance of the electricity mix in 12/2040 excluding photovoltaic

It is noted that the distribution has changed with respect to the situation of the spring substance, the contribution of photovoltaics is much lower, while the contribution from the wind is very high. The F1, F2, and F3 bands are very similar to the 2020 energy mix on a spring day compared to the 2030 electric mix on a spring day.

It is very important to note that to balance the demand during the day in the winter months there will be a lot of contribution from fossil fuels, this information will be very important in the following chapters

While for the summer substitute is show by figure 3-20 and 3-21:

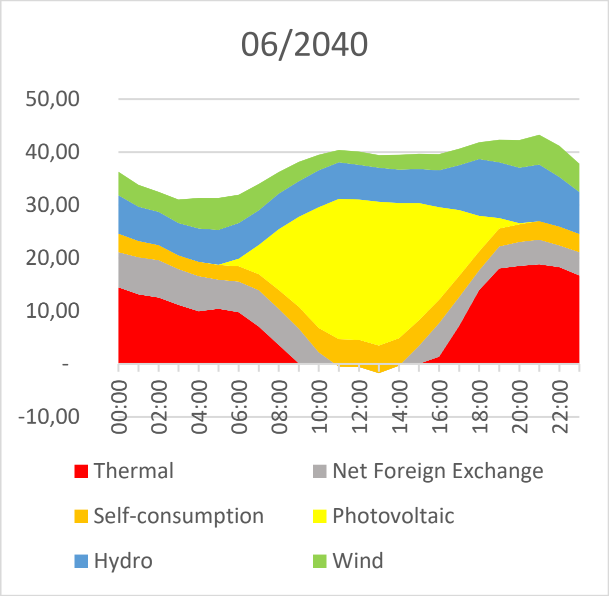


Figure 3-23 Balance of the electricity mix in 06/2040 without solar

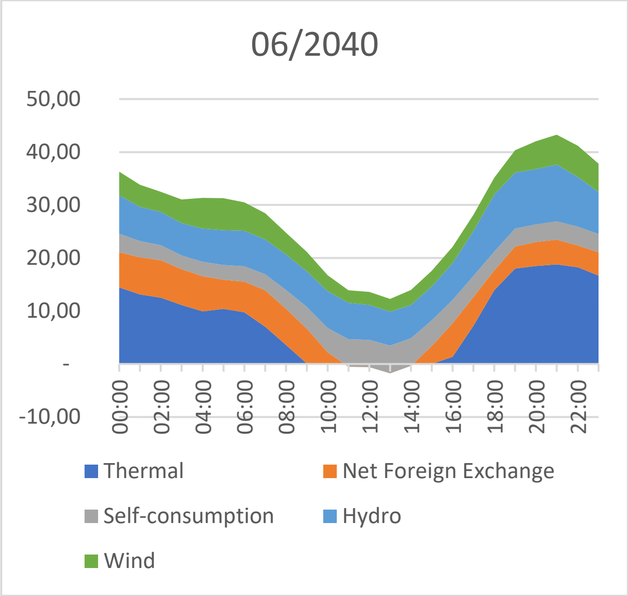


Figure 3-22 Balance of the electricity mix in 06/2040

As you can see from the figure, in the central hours of the day , it is expected that renewable sources will satisfy 100% of the energy demand, so there will be a great reduction in imported energy and energy produced by thermal engines. This information will have an important application in the following chapters.

The table 3-6 below makes a comparison between the representatives of typical days in 2040

	Energy balance 09/21/2040 (GWh)	Energy balance 06/21/2040 (GWh)	Energy balance 12/21/2040 (GWh)
Thermal	336.8	204.9	514.4
Net Foreign Exchange	149.3	105.5	22.2
Self- consumption	148.1	90.4	134.5
Photovoltaic	213.8	225.0	83.0
Hydro	126.4	179.9	113.1
Wind	171.5	98.7	370.3

3.2 Forecasts of usable energy sources in Turin

As already illustrated in the first part of the document, the energy center relies heavily on electricity and thermal power plants that produce electricity. In fact , it not only uses electricity as the protagonist of its air conditioning but also the district heating network.

“District heating is a form of heating which consists in the distribution through networks of insulated pipes (mostly underground) of hot, superheated water or steam (called heat transfer fluid), coming from a large production plant. With this system, the water reaches the homes operating in the heating or cooling systems, and then returns to the same plant at a lower or higher temperature "[15]

From the energy point of view, the district heating network is a pressurized water network with temperatures of about 120 °C which is charged through waste heat coming out of thermoelectric or simply thermal plants. From an energy point of view it is a very intelligent way to recover energy as from an energy point of view for the production of electricity it is useless as it has a very low temperature, on the contrary from the point of view of urban heating it is very important.

In fact, the heat obtainable thanks to cogeneration is proportional to the electricity generated through a thermal source. For example, if 10 thermal power plants can produce 1000 MW of electricity (with an efficiency of 24%), they will produce me extractable heat with cogeneration of 2333 MW (assuming a thermal efficiency of 56% and a total of 80%).

The connection that the district heating network has with the electricity produced by thermal sources is that if the demand from thermal power stations halves, the active thermal power stations will halve and therefore the heat supplied by district heating will be halved. This information will apply in subsequent chapters.

Nowadays, we notice that the district heating network is constantly expanding, this information makes it clear that although we do not know the potential of the district heating network of the city of Turin, we can assume that the demand for thermal energy from district heating actually exceeds supply.

As already mentioned in the previous chapters, the situation could change as in the following years we expect an ever greater production of energy from renewable energy and always less energy produced from fossil sources.

According to Arpa Veneto [16], the annual heating requirement for a family is about double that of electricity.

Making a limit hypothesis and assuming that every thermal plant in Italy is connected with a cogeneration plant, and assuming that these district heating plants have an electrical efficiency of 24% and a thermal efficiency of 56%, it appears that it is physically possible to heat not even 50% of the population. This value makes us understand that cogeneration has limits and cannot be expanded without thinking about it, moreover considering that the generation of thermal energy is destined to decrease, it could be even more risky to think of an expansion of the district heating network.

As we will see in later chapters, once the district heating network reaches saturation, one of the most cost-effective and energetic ways to continue growing the district heating network will be through the application of DSM-based strategies.

3.2.1 Situation in 2020, 2030 and 2040

As reported by Iren in a 2020 report [17], it certifies that the district heating network satisfies approximately 640 thousand inhabitants and in the same document it shows a continuous growth of the network until 2025.

Hence, from this growth it can be deduced that demand currently exceeds supply.

According to the study done in the previous chapters, on a typical winter day, about 465 GWh of electricity is produced from fossil sources at the times when the heaters are switched on or from (7:00 to 22:00), this value was taken as a reference.

In 2030, on the other hand, it is expected that the production of electricity from thermal sources in winter will drop to 465 GWh (-23.3% from 2021) while it will be 390 GWh in 2040 (-16.1% from 2021).

Returning to the hypothesis that demand in 2020 exceeds supply, it is believed that in the future winter periods there will not be an exaggerated decrease in electricity produced from fossil sources and therefore a huge imbalance of supply and demand in the field is not expected. of cogeneration.

The table below shows a hypothesis of how much thermal energy could decrease and whether this decrease is enough to slow down the evolution of district heating.

Table 3-6 Energy produced from thermal sources that favors the district heating network

		electricity produced by thermal from 7:00 to 22:00 (GWh)	difference from 2021	demand in equilibrium with supply
district heating	dic-21	465	0.0%	Yes
	dic-30	357	-23.3%	Yes
	dic-40	390	-16.1%	Yes
	giu-21	185	0%	Yes
	giu-30	no continuity	-	NO
	giu-40	no continuity	-	NO

The results of this table show that in the winter condition there will be a slight reduction of energy by the thermoelectric plant, especially in the hottest hours of the day, while in the summer conditions there will be a strong decrease especially in the hottest hours of the day. In conclusion, we can say that the district heating network will normally be loaded in the winter condition while it will not be loaded at all in the summer condition. This attention will be very useful for us to understand that summer district heating will disappear while winter district heating will continue to exist.

3.3 Historic world energy situation

Since the industrial revolution, energy consumption around the world has grown at a very rapid pace. In 1900, global energy consumption amounted to 22,000,000. This number has grown to the current 600,000,000 and is set to rise again. In fact , from 1990 to 2020 the energy produced is 50%. Currently 85% of the energy is produced by natural gas, fuel oil and coal, the remaining 15% of the energy is produced by the use of nuclear power, wood and renewables. The figure below shows the trend of the energy produced.

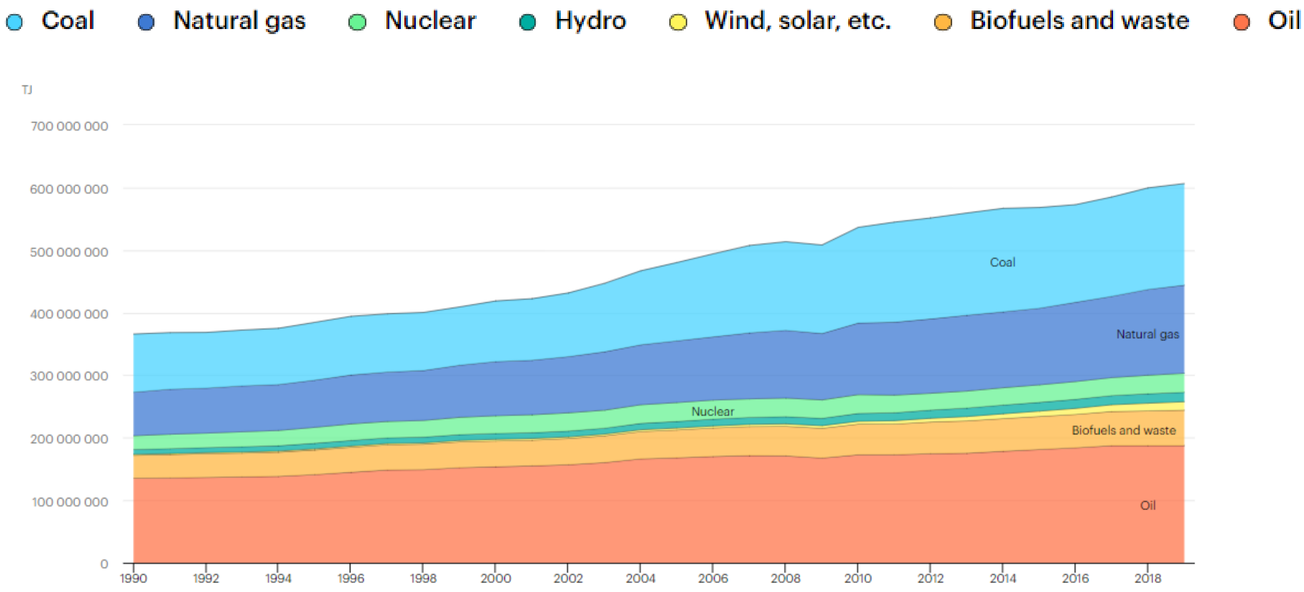


Figure 3-24 energy trend of the world energy mix

Going to specifically study the sources of energy, we note that not all fossil fuels pollute in the same way. In fact, we note that for the same amount of energy produced, coal is the most polluting fossil fuel while methane is the least polluting fuel. From the point of view of the pollutants introduced, these three energy sources produce almost 100% of the CO2 introduced into the grid for energy reasons

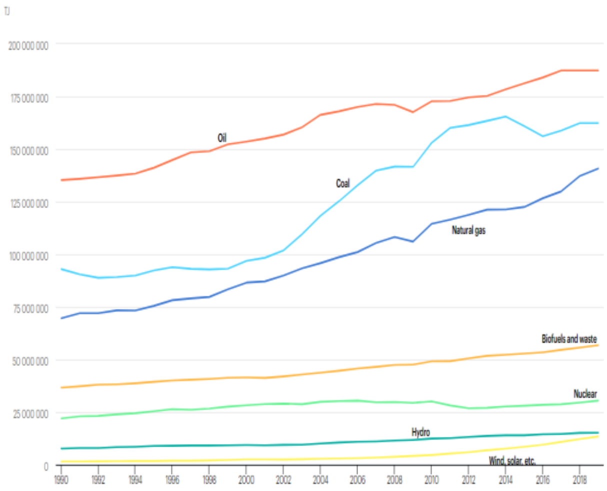


Figure 3-25 energy trend of the world energy mix

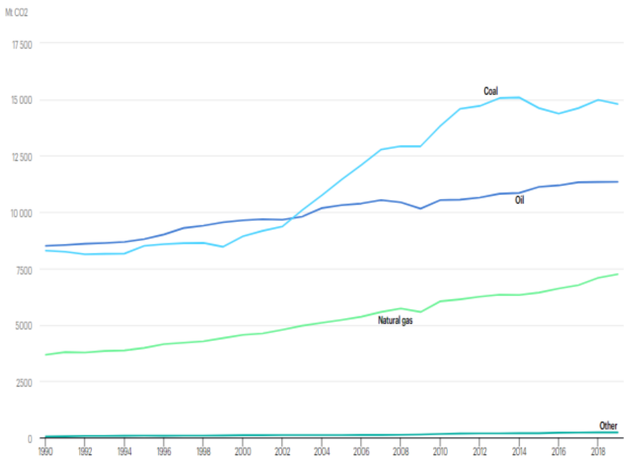


Figure 3-26 energy pollution trend of the world energy mix

● Coal ● Oil ● Natural gas ● Other

3.4 Historic European energy situation

The European energy situation in recent years is very different from the world situation. In fact , since 1990 we have not seen an increase but on the contrary a slight decrease in energy demand due to energy efficiency policies.

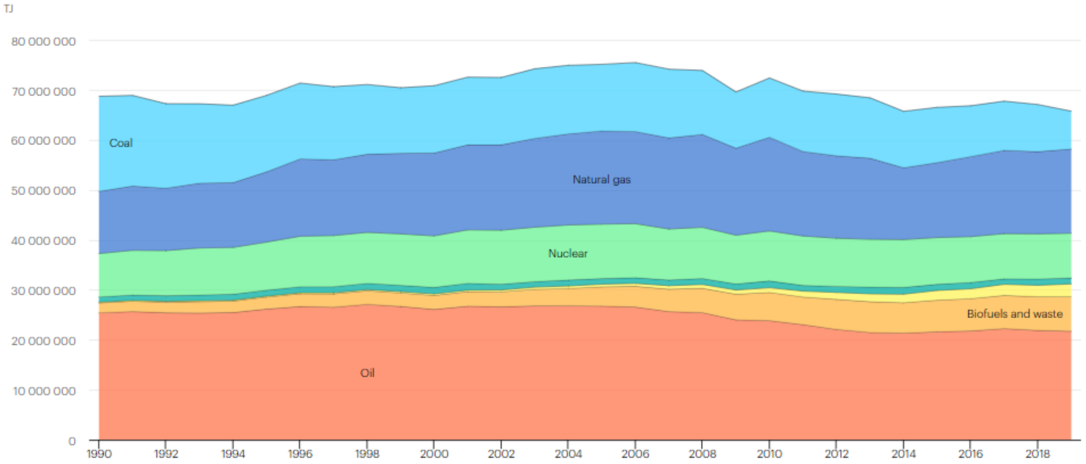


Figure 3-27 energy trend of the world energy mix

A very important feature of Europe is the energy transition towards less polluting energy sources. In fact , we notice a decrease in fuel oil and coal to make room for renewable sources which are biofuels, solar and wind energy which have had an enormous development in the last 20 years as shown in the figure.

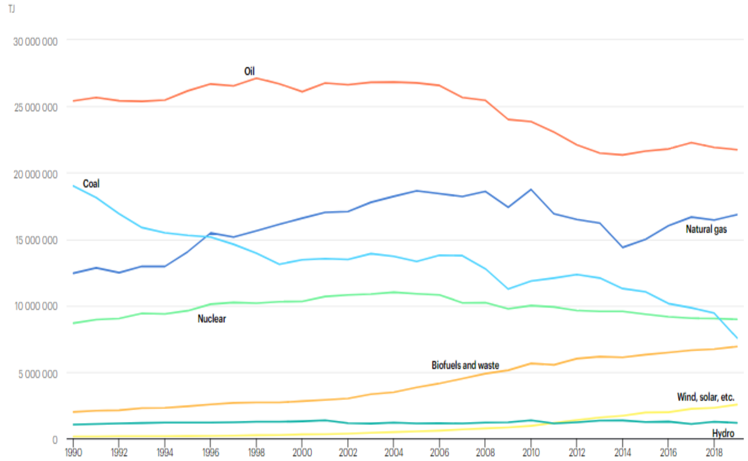


Figure 3-28 energy trend of the world energy mix

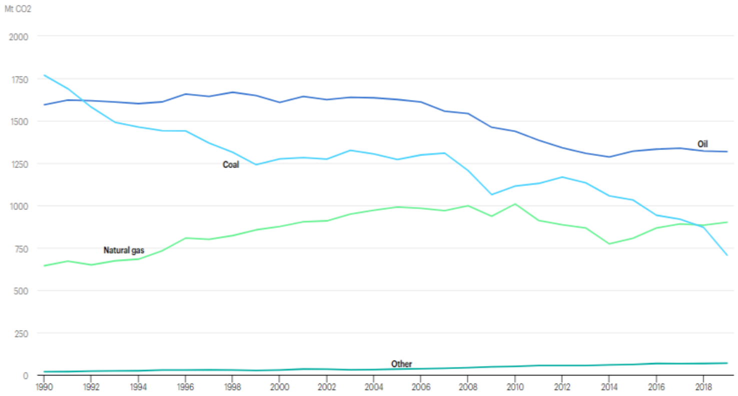


Figure 3-29 energy pollution trend of the world energy mix

3.4.1 European future electric generation mix

The study conducted in this report reports the forecast of future electricity demand by comparing it with current electricity demand. This study is based on predicted scenarios of the energy transition predicted by tern [13] .

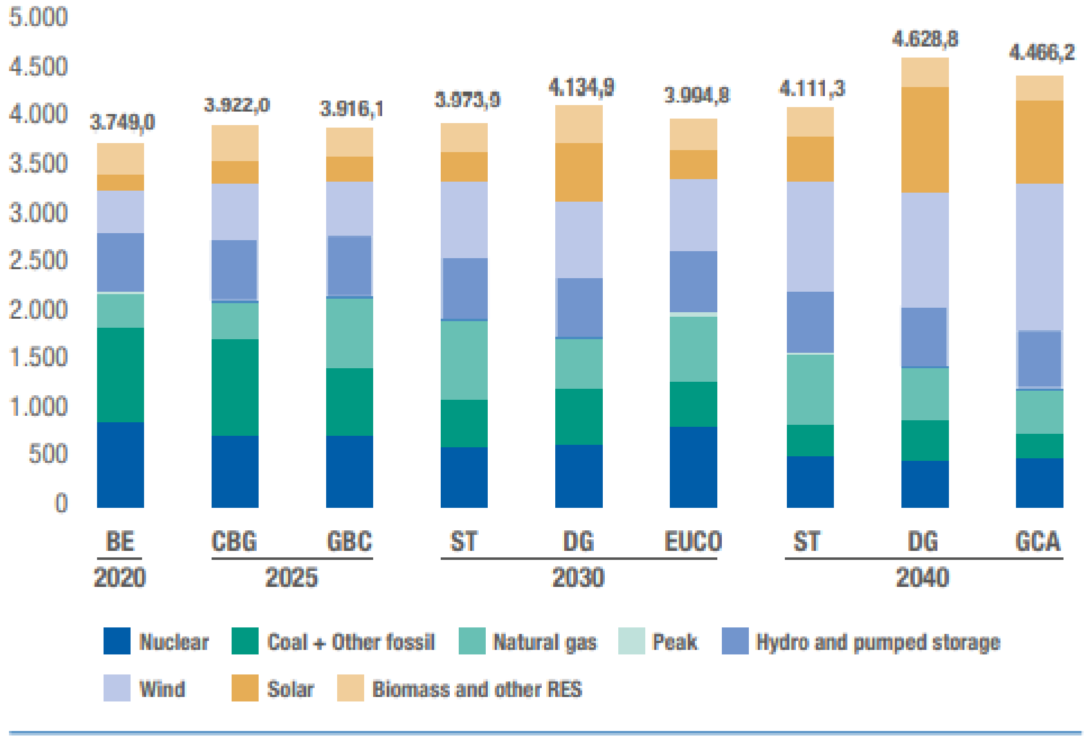
According to the study conducted by terna, the possible scenarios are:

- **Sustainable scenario Transition (ST)** sees a rapid and economically sustainable reduction of CO2 emissions by replacing coal and lignite in electricity generation with gas. The use of gas also partially replaces the use of liquid fuels in some sectors such as heavy transport. The electrification of heating and transport is proceeding more slowly than in the other scenarios for the achievement of the European CO2 reduction targets;

- **The Distributed Generation (DG) scenario** presents a development vision of the decentralized electricity system with a focus on the evolution of technologies to support end consumers. The latter play a central proactive role and electric vehicles have a high market penetration as well as photovoltaic installations and batteries in buildings. These developments involve high levels of Demand Response ;
- **The Global Climate Action (GCA)** is the scenario that requires the greatest effort towards decarbonisation. Great emphasis is placed on the development of renewable and nuclear power plants in the electricity sector. The electrification of heating in the residential and tertiary sectors leads to a gradual decline in the demand for gas in these sectors. The decarbonisation of transport is achieved through the growth of electric and gas vehicles. Energy efficiency measures affect all economic sectors.

In 2030 the GCA scenario was replaced by a complementary storyline **(EUCO 30)** modeled and prepared by a consortium led by E3Mlab and hosted at the National Technical University of Athens (NTUA), with the collaboration of the International Institute for Applied System Analysis (IIASA). In particular, the scenario illustrates the achievement of the climate and energy targets set for 2030 by the European Council in 2014 and includes energy efficiency equal to 30%.

The following figure 3-27 shows the development of the scenarios just mentioned with a comparison with 2020. The forecast goes from 2025 to 2040.



Fonte: TYNDP 2018 – Scenario Report –ENTSO

Figure 3-30 Comparison between the energy supplied and the energy mix of 2019 with 2025, 2030 and 2040 in TWh

4. Theoretical aspects of buildings

This chapter shows the concept of Demand-side Management (DSM) and thanks to several studies done over the years, what are the possible techniques to be adopted.

“DSM activities are those that involve actions on the demand side (or customer) of the electricity meter, stimulated directly or indirectly by users. These activities include what is commonly called load management, strategic conservation, electrification, strategic growth or deliberate increase in market share ". [30]

Thus "Demand management (DSM) refers to technologies, actions and programs on the demand side of energy meters, implemented by governments, utilities, third parties or consumers, to manage or reduce energy consumption through efficiency. energy, energy saving, demand response or on-site generation and storage, in order to reduce the total expenditure of the energy system or contribute to the achievement of policy objectives such as emissions reduction, supply and demand balance or reduction of consumers' energy bills. [31]

The concept of DSM is constantly evolving over time, in fact, the evolution of technologies, more mature and elaborate knowledge but above all an evolution of energy objectives have led the last twenty years to consider the concepts of DSM increasingly important . In the 80s with the energy crisis there was a first diffusion of the DSM guided therefore by energy saving, in our days instead to guide this study is the increase in the penetration of renewable sources guided in turn by the objective of carbon free within 2050.

4.1 DSM technologies

In the figure 4-1 [9] There is a scheme that distinguishes the DSM categories on the basis of the approach used, the technology implemented and the characterization of the application over time.

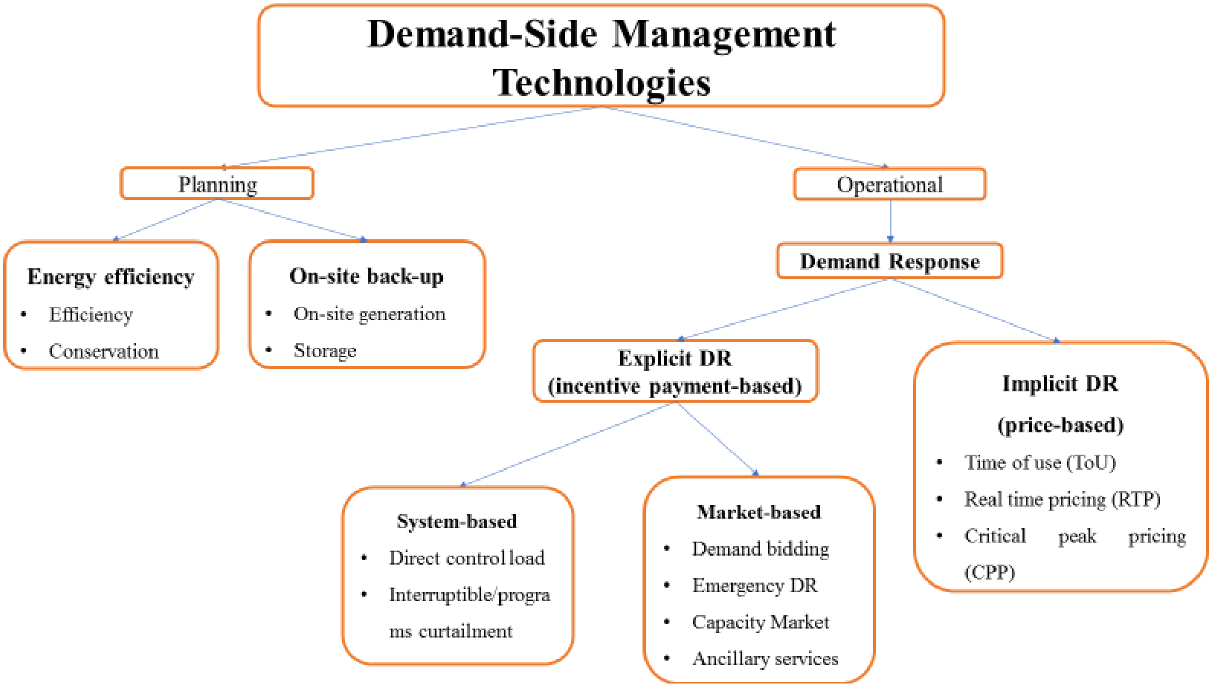


Figure 4-1 Demand-Side Management Technologies

The first distinction separates DSM technologies based on the time scale of the intervention considered. So we have:

- **Planning** : It includes interventions where the gain will be long-term. It is divided into two subclasses such as **Energy efficient** (such as the replacement of equipment with a more efficient one) and **On-side Back-up** (such as the installation of a storage generator)
  The main feature is therefore to have a long-term energy saving effect that can be considered "permanent" until the completion of a Planning action
- **Operational** : it includes temporary interventions due to changes in supply and demand. In this class we can distinguish further subclasses such as **Explicit DR** and **Implicit DR** , but both are event- driven .

4.1.1 Energy efficiency

Energy efficiency refers to the relationship between the service (which can be both energy and non-energy) and the energy paid. We have two phenomena concerning efficiency: **energy efficiency** And **energy conservation**

- **Energy efficiency** directly depends on the ratio of service obtained and energy consumption. So we have an improvement if the service obtained increases for the same consumption or if the service obtained remains constant in the face of a decrease in energy.
- **Energy conservation** refers to all those actions that aim to reduce the overall energy consumption while having a change of use by the user. An example is the variation of the temperature setpoint .

4.1.2 Distributed generation

Distributed Generation (DG) refers to small on-site generation and storage plants , therefore characterized by spatial and technological decentralization with respect to the main energy production that feeds the national electricity grid.

On-site generation therefore includes all solutions (usually of small and medium size) that have the generation of energy connected directly with the user and directly to the distribution network. This technology is often managed and controlled directly by the user (in many cases a company) and can be used for peak applications shaving or as a beck -up solution in situations of network unavailability or during periods of high energy costs [6]. It is useful to make a further distinction in this category: intermittent power technologies and stationary power technology .

Intermittent technologies are often generated from renewable sources and therefore their production depends on external causes. Alongside this technology there are often storage solutions capable of accumulating energy and releasing it in periods of need and scarcity of the primary source. A very important example is solar energy, which is present only during the sunny hours but absent during the night, so a storage technology would be a way to use energy when the sun is not present.

To help DSM activities there are storage technologies which, as already discussed, improve the use of energy.

The possible storage systems are many of different nature:

Mechanics how:

- rotational kinetic energy (standard) or translational kinetic energy (difficult for large energy storage) as flywheels
- gravitational energy such as hydro-pumped storage or energy vault towers
- eleastic energy (spring deformation)
- gas compression as compressed air energy storage (CAES)

Thermal

- thermal energy storage (TES)

Chemist

- storage of hydrogen.

Electro chemistry

- rechargeable electrochemical batteries such as lead-acid, lithium, nickel-metal hydride NiMH.

more expensive time slots . To incentivize the use of this storage, a Time-of-Use rate plan is required which distributes a different rate at each hour.

The main problems with this technology are the storage investment cost and the storage charge and discharge cycle, which averages 55%.

4.1.3 Answer to the question

The answer to the demand is represented by a series of actions that aim to incentivize or discourage the use of energy in a given time slot so that the energy demand comes as close as possible to the supply by decreasing the peak demand. which are more expensive for both the consumer and the seller than the basic demand. Usually this model is voluntary from the consumer's point of view and the energy is influenced by the three time slots (F1, F2, F3).

So the main objective of the DR is the reduction of the energy demand of the peak hours. This objective is achieved through two categories: **Explicit Demand Response and** Implicit **Demand Response** .

Explicit Demand Response it is what we commonly call incentives. We see this method explicitly with a bill payment due to the pre-contractual load form.

An actor that is gaining more and more importance is the role of the Aggregator . It represents a new figure that generates flexibility in the electricity network. It is connected to software that brings together many small powers, becoming a big load and selling its flexibility to the wholesale market.

Implicit Demand Response the price- based is typically what we know in Italy as a subdivision into bands F1, F2, F3. These programs are used to bring the supply and demand curve as close as possible and typically seek to decrease peak energy demand . The consumer also gets an advantage through savings in the bill as the energy used for each band is recorded.

The main categories of this answer are:

- Time-of-use (ToU) which corresponds to the hourly division by bands, these bands can change during the time of the day and during the season of the year (for example in summer there is a greater production of energy by solar compared to winter and this could change the time slots in the two seasons of the year).
- Critical Peak Pricing (CPP): is represented by a program in which high prices are set during peak hours. These peak hours are supposed a few days earlier and need a more active response from the user.
- Real-time price (RTP): it is the price of electricity that generally fluctuates throughout the day. Therefore, energy consumption reflects as much as possible the dynamics of the wholesale market price.
- Peak-Time Rebates (PTR) are tariffs that remunerate end users in order to reduce consumption compared to a calculated hourly consumption.

4.2 DSM strategies

The strategies DSM's main features are of six types: Peak clipping, load shifting, flexible load, strategic load growth, strategic conservation and valley filling. The figure 4-2 graphically shows how DSM technologies work

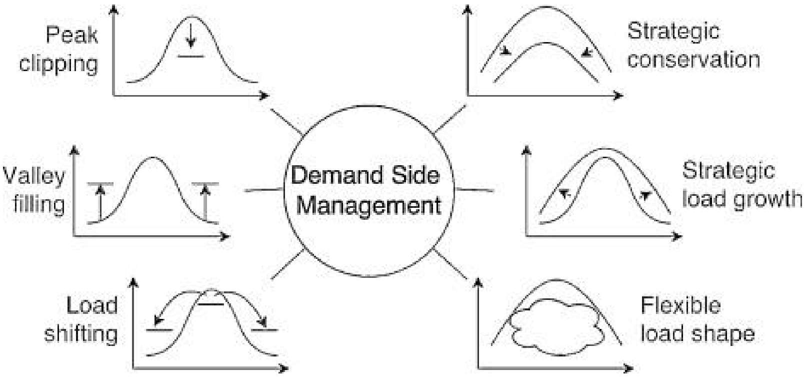


Figure 4-2 Strategies of Demand Side Management

[21]

- Peak clipping represents the reduction in peak demand, typically the peak time is the time of maximum energy demand
- Valley filling means greater use of energy during off-peak hours. An example when there is a very high production during off-peak hours. This strategy will be heavily studied in the future as an increase in renewable energies is expected
- Load shifting is the strategy that shifts the load from peak to off-peak periods. This strategy is one of the most important as many times a renewable and non-renewable energy source are limited to having a constant or unpredictable production throughout the day, so help from the demand side is appreciated to balance the balances.
- Strategic load conservation aims to reduce overall energy consumption . This strategy goes hand in hand with increasing energy efficiency.
- Strategic load growth reflects an overall increase in energy demand. This increase is typical of developing countries as it is related to a country's economic growth. In developed countries, on the other hand, it is linked to a change in technologies used for air conditioning or for transport.
- Flexible load shape is a concept historically linked to the offer. However , with a view to increasing energy efficiency and therefore energy saving. This strategy is based on the need to balance demand with supply. This strategy specifically tries to match as much as possible the theoretical demand of the day with the real demand.

4.3 Energy saving strategies

Considering the load systems, it is possible to classify buildings according to their characteristics and the way in which energy flexibility can be managed. First of all, it is necessary to distinguish between loads that have a potential for flexibility with those that do not . The potential for flexibility is often linked to the use of the system itself and therefore to the service for which it is intended. According to [6] it is possible to distinguish:

- Thermostatic loads : whose operation is linked to a temperate set point. In this category the most important loads of buildings: heating, cooling and DHW.
- Movable loads: whose operation can be moved over time without compromising the service. A domestic example is the opening hours of washing machines or dishwashers
- Decurtable loads: These are those loads that include services whose operation can be deactivated or reduced when necessary. This load is often represented by lighting.

- Loads that cannot be shortened: This includes loads that cannot be reduced or interrupted. These loads are represented by safety systems or appliances that cannot be turned off (such as the refrigerator).

4.4 Strategies for implementing energy flexibility

Energy flexibility is often defined as the deviation in time or power that a unit can offer with respect to its basic operation. To provide this deviation it is possible to exploit energies generated in logo, energy storage or modify the load model of the different energy services installed in the building. The models of the strategies are:

- **Temperature adaptation** : This strategy is based on changing the set point temperature. This change can be set either to raise the setpoint temperature or to decrease it. It represents the most effective strategy because it can reduce all the loads related to that service. This strategy requires the presence of devices capable of reading temperatures and controlling the heating or cooling system. This type of flexibility changes a lot depending on the user.
- **Passive thermal mass storage.** This strategy provides for the storage of heat during off-peak hours (or when there is an energy source of environmental origin). So this strategy provides at least two setpint temperatures as one value is designed for energy storage while the other for storage consumption
- **Reduction of ventilation capacity.** This reduction is one of the most important reductions since reducing the flow rate means reducing the flow of air passing through the heat exchanger, thus reducing energy consumption. This method of reducing the flow rate can be done in several ways such as: decreasing the fan speeds or through lamination. The most efficient method is to reduce the number of revolutions of the fan; however, when this is not possible lamination is used at the inlet or outlet of the heat exchanger. Very often, these two of these combinations are used at the same time for greater control.

As far as energy saving strategies are concerned, here too we have the constraint that they must be designed in such a way as not to decrease the productivity of the occupants. Therefore in the lighting sector the available strategies are [32]

- **Light switching:** That is the control of the light on entire areas or a fraction of flashes in particular when artificial light is not needed. This type of control is very traditional in both residential and office buildings. It has no good energy saving potential when there are unused common areas. This regulation system has been superseded by a sort of automatic lighting capable of perceiving whether or not there are occupants in the affected area.

- **Gradual dimming:** This control allows you to have both on and off lamps in the same zone. This control is very pleasant as it allows the occupants to choose an intermediate light density without choosing between two extremes such as light on or light off.
- **Continuous darkening:** it represents the evolution of the gradual darkening. In fact , both these strategies have a control of the light density (and therefore of the power) but while the first is based on turning off some lights while leaving others on, the continuous dimming is able to regulate the density of light (and therefore of power) delivered by each lamp thus allows better control.

It is very important to keep in mind that flexibility strategies affecting load utilities can affect operation and productivity, causing possible discomfort effects. Therefore, in applying these strategies for some programs, such as Demand Response , a certain minimum level of comfort for the occupants must be guaranteed. In fact, the aim of the strategies presented must be to achieve the demand saving objective without compromising the productivity of the occupants and the activity they are carrying out. In particular for Commercial Buildings, as suggested by Aduda et. Al [6] the cost of labor represents a constantly higher part than the cost of energy; therefore, ensuring the comfort of workers is a fundamental requirement.

Thermal comfort is defined by the ASHRAE 55 standards as: " *Mental condition expressing satisfaction with the thermal environment* " [33]. This definition makes the subjective nature of thermal comfort understandable, which can be perceived differently by each occupant. Furthermore, it is influenced by several factors that need to be taken into account for its evaluation, which are metabolic rate, clothing insulation, air temperature, radiant temperature, air velocity and humidity. The most popular thermal comfort model that includes all these parameters is the Predicted model Mean Vote (PMV), introduced by Fanger et. Al. In 1970 and later adopted by the ASHRAE and ISO [6].

So the installer's goal is to design a system that allows well-being inside the room and therefore to have PMW as close as possible to 0 and consequently have a Predicted Percentage Dissatisfied (PPD) as low as possible.

4.5 Factors affecting energy consumption

For a correct state of comfort and therefore a correct energy management it is necessary to identify the factors that can influence the energy demand. The energy demand is therefore not constant over time but has several variables, the most important variables that influence the energy demand are:

- **External conditions:** The consumption of a building, in particular the heat consumption, is strictly dependent on the external conditions. The external conditions in turn depend on numerous factors which are: geographical position (latitude, ground reflection coefficient, etc), time of year (season), time of day and weather conditions. In general, the external conditions fixed for a rental are predictable according to the season. However, this forecast is very rough as daily weather conditions can deviate from average seasonal conditions.
- **Construction characteristics:** The construction characteristics of the building are meant, such as: transmittance of the walls, transmittance of the components with windows, thermal bridges, etc. They depend mainly on the surface of the building, the shape of the building and the materials used for the construction of the property.
- **Occupancy:** Occupancy of buildings is often a very important parameter to consider, especially for offices. Each occupant generates a quantity of sensible and latent heat, in addition, a certain value of external ventilation is provided for each occupant.
- **Operation:** This refers to the way in which thermal comfort must be achieved. Very often, depending on the operation, reference parameters change from the point of view of employment and from the point of view of equipment. For example , forced ventilation inside a gym with the same construction characteristics and occupants must be much greater than ventilation in an office. This is because the occupants in a gym typically consume more oxygen than the occupants in an office.
- **Passive equipment** : equipment refers to all systems that produce heat. Very often the thermal impact of some equipment is neglected as they are not influential; however, it cannot be neglected as there are many machines (especially in the industrial field) that produce a non-negligible thermal load.
- **Active equipment: The equipment** sector also includes energy management equipment (thermal and light) such as equipment that provides heating, cooling, lighting, ventilation, etc.

Once the factors that influence the energy factors have been defined, it is possible to evaluate some control models in such a way as not to oversize or undersize the power to be supplied to the system in such a way as to reduce the unsatisfied percentage index to a minimum. The models that develop the control can be divided into three categories:

- **Stationary models:** these are models in which the power supplied is constant over time and does not vary according to the factors that influence the temperature
- **Quasi-stationary models:** they are models that base their operation on stationary calculations (such as stationary models) but their operation changes monthly based on average monthly values
- **Dynamic models:** they are models in which they base their functioning on the factors that influence energy in real time; therefore, they can change their operation hour by hour according to the specific situation. In these models the DSM finds a large space for optimization as thermal comfort can be associated with a better management of energy peaks.

4.6 Building management

Building management always involves a series of often sequential operations. Motegi et. Al [34] proposed a general framework from gathering information to verifying effectiveness, in order to ensure the main objectives of these implementation strategies:

1. Gathering of information: It concerns the collection of all available information that can be useful in planning energy saving and flexibility strategies. Reading systems and histories of energy consumption can be included in the planning.
2. Building performance simulation: They are simulations capable of predicting the dynamics of buildings before the start of the works in order to choose not only if a strategy is applicable or not but also to choose the best strategy to apply. In this way, the customer is able to evaluate the quality of the investment with greater reliability and therefore evaluate the economic and environmental return over time.
3. Sequence of Operation Strategies. In this strategy, a sequence of procedures is drawn up for the physical construction of the plant. Some of these procedures can be carried out in parallel and others necessarily in sequence
4. Potential estimate. It corresponds to the complete analysis of the various strategies drawn up. In this phase the most suitable cost / benefit configuration is chosen considering not only the system in its economic nature but also from the point of view of comfort.
5. Performance monitoring plan: The simulation tool can only provide a preliminary evaluation on the analyzed strategy; however, experience teaches that a preliminary test is not enough to

test a system over time as very often problems not thought of in the design phase are encountered. Therefore, constant monitoring of the plant is necessary and above all the place where the plant monitoring tools must be placed must be planned in advance.

6. Proof -of-concept. It represents the practical test of the system. In this test a practical estimate of the energy saving of the system is made, it is preferred to only the theoretical test as it is more reliable. The problem with manual testing is that it often depends on external conditions that often differ from the standard conditions on which the theoretical simulation is based. A manual test performed well has the same physical and operational conditions as the theoretical simulation (irradiance, weather conditions, number of occupants, etc ...)
7. response strategy proposal . The control strategies whose simulations have been successful are presented to the service administrator together with a proposal of their sequence of operation relating to the economic cost-benefit plan
8. Install the demand response strategy . If the strategies presented are accepted, any additional tools necessary for operation are installed.
9. Post installation test. This test is necessary to evaluate in practice the correct functioning of the strategy and the benefits obtained from it
10. Post-installation check. It provides for continuous monitoring of the functioning of the system over time. So it not only helps to understand if the cost-benefit ratio is long-lasting but also if there are problems in the operation of the system. The post-installation verification is currently carried out online in real time so that the professional can observe the system even remotely as carried out by the company of ARCOSERVIZI SPA in Turin.

4.7 People in the management of systems in buildings

For the design, construction and management of systems in buildings, it is necessary to know who is responsible for taking care of them. These figures are represented by:

- The Building Administrator who is a delegated representative of the property owner (who may be the owner himself). This figure establishes the objectives to be achieved and is the figure who has the task of approving all the interventions that must be applied always taking into account the cost / benefit ratio.
- The Energy Manager who has the task of studying the energy efficiency plans to make a well-detailed plan of the building's cost / benefit ratio. In Italy its role is specified by UNI CEI 11339.

- Facility Manager, I present only for complex plants that need more people who take care of the management. They often deal with the management, regulation and distribution of energy systems. Their task is to ensure the comfort of the occupants and coordinate with the energy manager.
- Controls contractor is the figure that deals with the control of the plant and automation. This figure is often managed by a specialized company and in the event that the control must be carried out on large plants , this control is carried out by an energy monitoring staff. Their task is to monitor operation to improve the comfort condition and detect possible anomalies in the system. In the event that DSM strategies are implemented their task is to monitor the plant in order to collect data.
- External Partners. These are figures who often have a specific role and perform what the reference company fails or cannot do. A specific example where an external partner may be required are in DSM applications as most companies don't bother making a specific strategy
- Researchers. This figure is almost never present in the plants as they often work for academic and development organizations. They can provide different contributions to the project as external partners. Their characteristic is that they often have access to very expensive or difficult to find texts in literature.

The role of each figure, both in general terms and specific to the DSM, is described in the following table

Table 4-1 roles in the management of a building

	General	DSM
Building administrator	Final choice of the possibilities listed by the other figures, always keeping in mind the cost / benefit ratio	Final choice of the possibilities listed by the other figures, always keeping in mind the cost / benefit ratio
Energy Manager	Monitor energy consumption by proposing energy efficiency measures and use of energy or renewable sources.	Evaluate the effect of applying DSM strategies
Facility managers	Manage equipment programming and operation. Technical system maintenance program.	Act to change the appliance operation setting.
Control contractors	Install automation hardware and software and control system.	Provide support for programming BACS and modifying initial algorithms.
Energy monitoring personnel	Collect tracking data by making it accessible to other players.	Collect the data of the points monitored during the whole process.
External partners	Direct in charge of studying and implementing interventions or able to provide support to internal actors.	He can be directly assigned to conduct the entire study and implementation work or he can provide support during specific phases.
Researchers	Leverage all available resources to contribute to academic research.	Use the building as a case study to develop simulation models or evaluate new DSM strategies.

Making a general overview we can observe in the table which figures are authorized and indicated to do the specific tasks. The table [9]shows in the columns the type of tasks numbered 1 to 10 explained in the chapter and the table 4-2 chosen by rows. In case of X it means that that specific figure can perform that specific task.

Table 4-2 roles and responsibilities in the management of a building

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Building administrator	**X**									
Energy Manager	**X**	**X**	**X**	**X**	**X**		**X**		**X**	**X**
Facility managers	**X**		**X**			**X**		**X**	**X**	**X**
Contractor checks					**X**			**X**		
Energy monitoring personnel	**X**				**X**	**X**		**X**	**X**	**X**
External partners	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Researchers		**X**	**X**	**X**	**X**		**X**		**X**	**X**

5. Case study: Energy center

The Energy Center inserted in an area that includes just under 5 000 m2 located in via Polo Borsellino 38. The entire area consists of an office building, research laboratories and a large courtyard as shown in the figure 5-1.

Figure 5-1 Energy Center

The Energy Center aims to build national and European networks as an incentive for the development of new entrepreneurial initiatives in the energy sector through the opportunities provided by academic research, innovation and partnership .

The Polytechnic of Turin launched the Energy Center Initiative (ECI) in 2016. According to Energy Center [22] The two main pillars are:

- **the Energy Center House (EC-H)** is a new building on the campus of the Politecnico di Torino that will host companies, start-ups and public administrations and other subjects active in the sectors of R&D, management, policy and decision -making in the energy field;
- **the Energy Center Lab (EC-L),** the Interdepartmental Center for Energy, which brings together a multidisciplinary group of researchers and professors of the Polytechnic dedicated

to the study of integrated technologies and systems for the transition to a more sustainable society towards use energy and the environment.

The thesis proposal of Demand-side Management therefore represents an opportunity for Energy Center Initiative to provide support and knowledge to leased and national entities and could become one of the few national references in the real implementation of DSM strategy. Therefore the aim of this work is therefore to investigate the energy flexibility potential of the building.

Unfortunately, due to the high complexity of the building and the inaccuracy of the measured values as they are often anomalous, the possibility of generating a detailed model on the implementation of the strategy was excluded.

5.1 Description of the building

The building has a gross volume of 36253 m3, about 16 m high. It has a dispersing surface of approximately 7120 m2 of which 4840 m2 is done on the external side while 2280 m2 overlook the ground as the building has a basement.

The spaces of the building are shown in table 5-1 [23]:

Table 5-1 Description of the building

		Sup (m2)	Vol (m3)
FLOOR	UNDERGROUND	3602	10624
FLOOR	EARTH	1465	9397
FLOOR	MEZZANINE	424	1548
FLOOR	FIRST	1369	4588
FLOOR	ACCORDING TO	1369	4577
FLOOR	THIRD	1369	4568
FLOOR	COVERAGE	1533	951
TOTAL	Spaces	11132	36253

Where Sup means the walkable surface and Vol means the gross volume.

The basement has a parking area of about 50 cars and the technical rooms that house the heating and cooling systems, the fluid distribution system, five air handling units (AHU) and the emergency diesel generator.

The ground floor houses a reception room, an auditorium and a laboratory.

The mezzanine floor presents the control room where the PC room is installed through which it is possible to manage the building supervision system.

On the first, second and third floors there are offices that welcome private companies and researchers.

The main players in the energy sector are:

- Electricity: which supply is produced by photovoltaic panels and microturbines and the missing energy portion is taken from the grid
- Heat: which supply is taken from the district heating network and from various heat pump systems. On the ceiling there is a small solar thermal system used for experimental uses.

5.2 Energy center air conditioning

The building is located in Turin and therefore belongs to the climatic zone E. According to the UNI 5364 standard, the average external values to calculate the heat required in the winter months is -8 °C and a relative humidity of 81% while in the summer season the average values are 31 °C with a relative humidity of 50%.

The desired thermohygrometric conditions are:

- Winter season: 20 ± 2 C with 50% ± 5% relative humidity
- Summer season: +26 ±2 C with 50 % ± 5% relative humidity

Taking into account the presence of people estimated according to the tables of the UNI 10339 standard depending on the destination of the premises.

As happens very often in buildings, not all thermal zones are heated / cooled in the same way with the same type of heat exchanger, in fact the different thermal terminals found in the energy center are:

- Floor panels
- Ceiling panels
- Primary Air
- Radiators

- Air extraction with renewal by means of a recuperator
- Local system with electric fan heater that intervenes when the temperature drops below 4 °C from the design temperature
- Full-air system

As already mentioned in the introduction, the Energy Center has several technologies related to energy.

In fact, among these we have the connection with:

- the district heating network
- polyvalent group for the temporary production of cold and hot fluid
- absorption refrigeration unit
- photovoltaic panels for the production of electricity
- solar contraction panels
- electric kettle when using domestic hot water at night.

A characteristic of the energy center is therefore of different sources of heat production entirely connected to each other. In fact, we have that the domestic hot water works with the combination of district heating, heat pump, solar concentration panels and electric kettle. The cooling system uses the district heating network and electricity as an energy source by exploiting an absorption refrigeration unit and a multipurpose heat pump that uses groundwater. The heating system, on the other hand, is supplied by a system that couples the district heating network with the multipurpose heat pump that uses groundwater as an energy vector.

5.2.1 Photovoltaic system

The Energy Center has a photovoltaic system with a nominal power of approximately 47 kW. The photovoltaic system is divided, as shown in figure 5-2, into four smaller systems, the main characteristics of which are shown in the table **Errore. L'origine riferimento non è stata trovata.**. In particular, it is possible to identify two self-supporting installations in correspondence with Stairs A and B and two integrated building solutions for the Facade and Roof of the Pavilion.

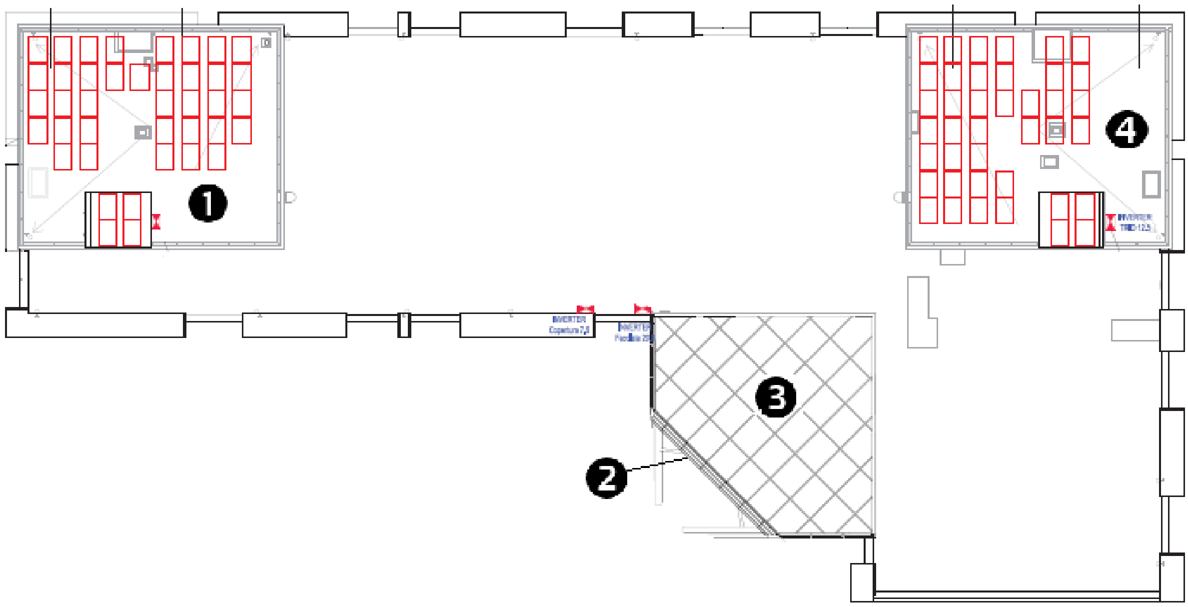


Figure 5-2 Solar system position diagram

Table 5-2 Solar system property

Photovoltaic system	P n (As-built) [kW]	Surface [m^2]	Angle of inclination	Azimuth angle °
Scale A	13.08	~ 65	10 °	+ 27.5 °
Facade of the hall	13.23	~ 80	80 °	-18 °
Hall coverage	8.02	~ 51	15°	-18 °
Scale B	13.08	~ 65	10 °	+ 27.5 °

5.2.2 Photovoltaic production analysis

As already mentioned in the previous chapters, the energy center has a modest area dedicated to the production of electricity through the use of photovoltaics. The construction technology of the photovoltaic panels is of monocrystalline silicon. As already mentioned, the energy center has many attractions from an academic point of view, for this reason it was decided to divide the energy production into four independent sites with independent inverters in order to study the different construction choices. The four sites are:

- Scale A
- Facade of the hall
- Roof of the hall
- Scale B

Using the monitoring of the whole 2018 and the irradiation values provided by ENEA it is possible to provide the following values:

Table 5-3 Comparison of photovoltaic system

Photovoltaic system	Pn [kW]	Surface [m 2]	Angle of inclination	Azimuth angle *	Irradiance [kWh]	Production [kWh]	Yield
Scale A	13.08	65	10 °	+ 27.5 °	91715	4355.554	4.7%
Facade of the hall	13.23	80	80 °	-18 °	93200	9922.836	10.6%
Hall coverage	8.02	51	15°	-18 °	70431	2137.158	3.0%
Scale B	13.08	65	10 °	+ 27.5 °	91715	8680.728	9.5%

As is often the case in real calculations, the measured values are often not accurate. This can be seen by showing the different output yields for the same type of photovoltaic; in fact, the scale A and scale B implants are twins and their production should be very similar, however there is a huge difference probably explained by the wrong measurement or by some malfunction. For the same reason it is not possible to take the values coming out of the scale coverage as truthful as it presents a too low yield.

Personally I would like to make a very important praise on the project on the choice of installing photovoltaic panels with an angle of inclination of 80 ° as, as highlighted in the following table, it presents a respectable production compared to the B scale.

Table 5-4 Comparison of photovoltaic system

Photovoltaic system	Surface [m 2]	Production [kWh]	Production / area [kWh / m2]
Facade of the hall	80	9922.836	124
Scale B	65	8680.728	134

As shown in the table, the photovoltaic production with an angle of 10 ° is perfectly comparable with that with an angle of 80 ° with the difference that in the case of an almost vertical inclination we will have an almost constant production throughout the year, while in the case of an almost horizontal inclination we will have a production almost only in the warm months.

Table 5-5 Comparison of photovoltaic system over the course of the year

Month	Production scale B [kWh / m2]	Facade production [kWh / m2]
January	0.17	0.29
February	0.24	0.32
March	0.35	0.38
April	0.43	0.36
May	0.50	0.35
June	0.57	0.36
July	0.60	0.39
August	0.53	0.41
September	0.41	0.40
October	0.27	0.32
November	0.16	0.24
December	0.14	0.25

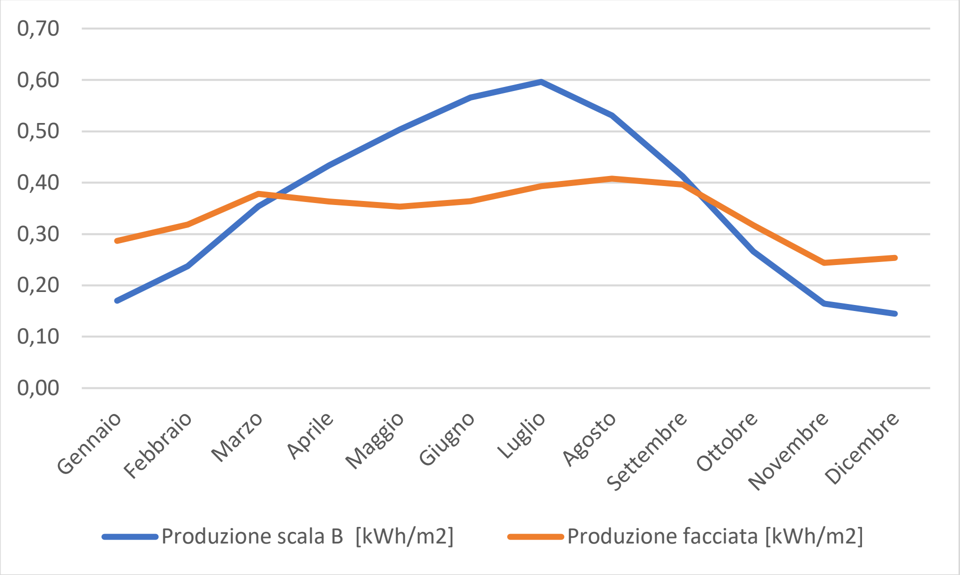


Figure 5-3 Comparison of photovoltaic system over the course of the year

5.2.3 Wind power plant

The wind power plant located on the roof of the polytechnic is purely demonstrative. It is composed of a microturbine with a vertical axis and a horizontal axis as shown in the figure 5-4 and 5-5.

Figure 5-4 vertical axis turbine

Figure 5-5 horizontal axis turbine

The figure shows a hybrid vertical axis turbine or formed by a darrieus turbine on the external blades and a savonius turbine on the internal blades. Its characteristic is the low cut speed in wind or 2 m / s

The figure shows a micro turbine with a horizontal axis formed by 5 blades and a tail that allows you to position yourself in favor of the wind. Its main feature is the low cost and a not negligible energy production when there is a strong medium wind. The cut in speed is 2.5 m / s.

Unfortunately the wind turbines on the roof do not produce enough energy to officially enter the electricity mix of the energy center, so they are used only for demonstration, study and research purposes.

5.2.4 Thermal plants

The technical room for heat management is located in the basement and is used for the production of heating, cooling and DHW. For the production of heat is therefore used:

- The multipurpose group, a figure that uses the aquifer as a source of heat in the winter and as a cold well in the summer. The wells made are two of 70 cm in diameter and 45 m in depth that can function as a withdrawal and as a drain. The fluid used as an energy carrier in the polyvalent group is R134a and the heating / cooling strategy is indirect; therefore, in the evaporation / condenser they will be used as heat exchangers for the fluid that will heat / cool the environment
- Heat exchanger for district heating.
- Heat exchanger for DHW
- Heat exchanger for the absorption refrigeration unit which is currently no longer used as it requires a high temperature of the district heating network circuit even in summer, however this temperature is not always reached as, as we have seen in the previous study in chapter 4, thermoelectric plants that produce energy during the day are often turned off because the water in the district heating network does not meet the minimum heat requirements for the activation of the multipurpose group. The reason for what happens can be found in the production of electricity as on the one hand we have the decrease in power of the thermoelectric plants (as explained in chapter 3), while on the other we see that the thermoelectric plants prefer to start a combined cycle rather than sell to the district heating network in the summer.

Figure 5-6 absorption heat pump [9]

The main technical data of the equipment needed for heat production is summarized below in the table below:

Table 5-6 Description of air conditioning machines

		Parameter	**Value**
Polyvalent Geothermal Group **(water-water)**	Heating mode	POLICEMAN	4.44
		Heating capacity (kW)	473.7
		Absorbed power (kW)	104.7
	Cooling mode (without reset)	EER	5.65
		Cooling capacity	442.7
		Absorbed power	73.7
	Cooling mode (with Recovery)	TER	7.94
		Cooling capacity (kW)	362
		Absorbed power (kW)	103.4

Absorption chiller		EER	0.7
		Absorbed by heat (kW)	~ 200
		Absorbed power (kW)	2.5
District heating (heat exchangers)	Heating	Rated power (kW)	350
	DHW	Rated power (kW)	50
	Absorption chiller	Rated power (kW)	255
Accumulations of thermal energy	Hot water	Capacity (m3)	4
	Cold water	Capacity (m3)	4
	Solar thermal system	Capacity (m3)	1
Sanitary boiler	DHW	Capacity (m3)	1.5

Table 5-7 Description of auxiliary services

Pump ID	**Scope**	**Installed power [kW]**
EP1	Aquifer - Well A	30
EP2	Aquifer - Well B	30
EP3	Multipurpose Group - Cooling	4
EP4	Multipurpose Group - Heating	5.5
EP5	Absorption chiller	2.2
EP6	AHU - Cooling	2.2
EP7	Radiant ceiling panels	3
EP8	Radiant floor panels	0.43
EP9	Radiators	0.75
EP10	AHU - Heating	4
EP11	Fan heaters	0.13
EP12	District heating - Heating	2.2
EP13	District heating - DHW	0.39
EP14	Recirculation pump	0.03
EP15	Solar thermal circuit	0.35
EP16	Cooling water - CED / UPS	0.12
EP17	UTA - Antifreeze	0.75
EP18	Absorption chiller - Dissipation	/

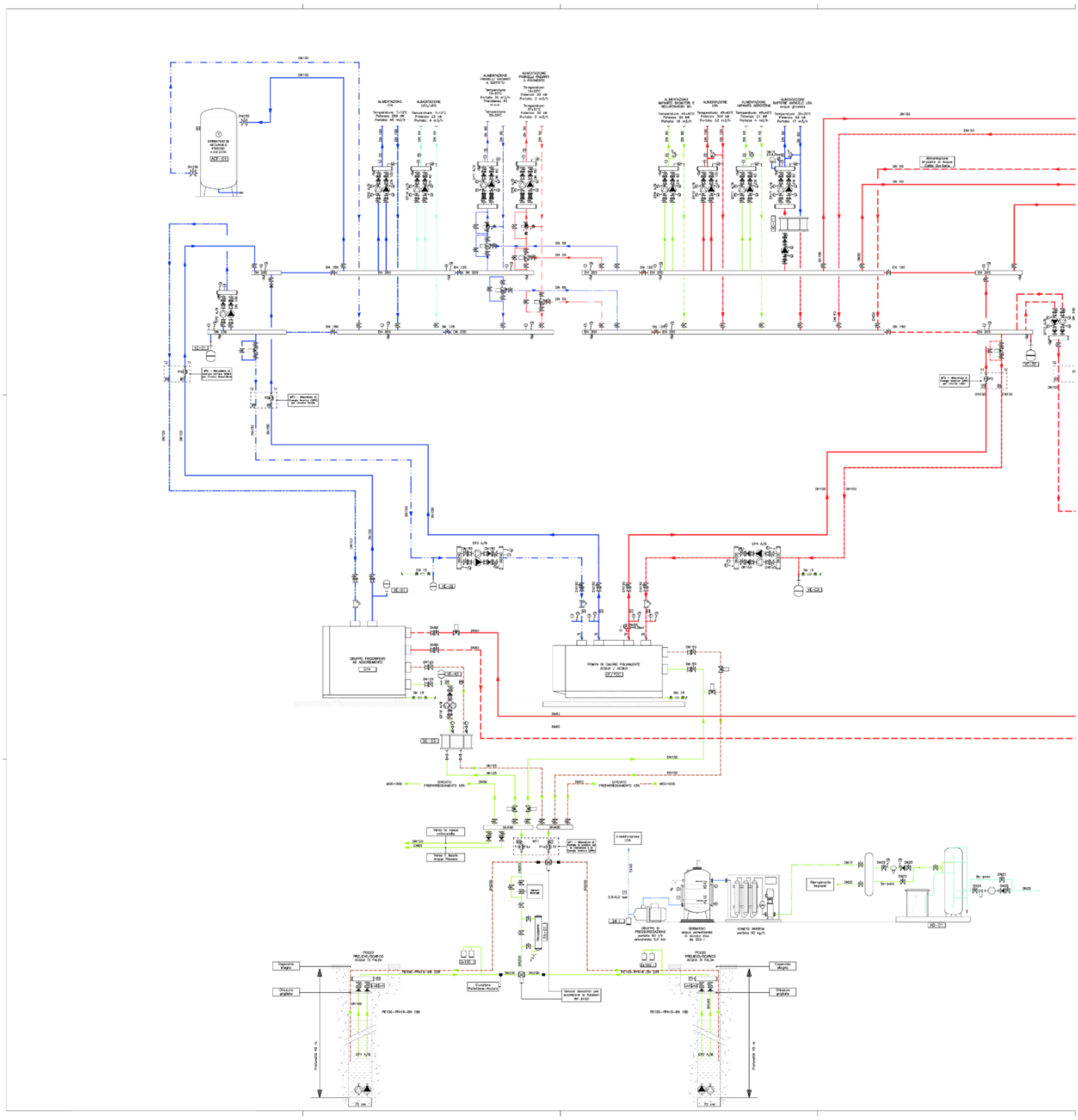


Figure 5-7 System diagram part A

1. Polyvalent Geothermal Group
2. Wells of the aquifer
3. Absorption chiller
4. Fresh conservation
5. Cooling system manifold
6. Heating system manifold

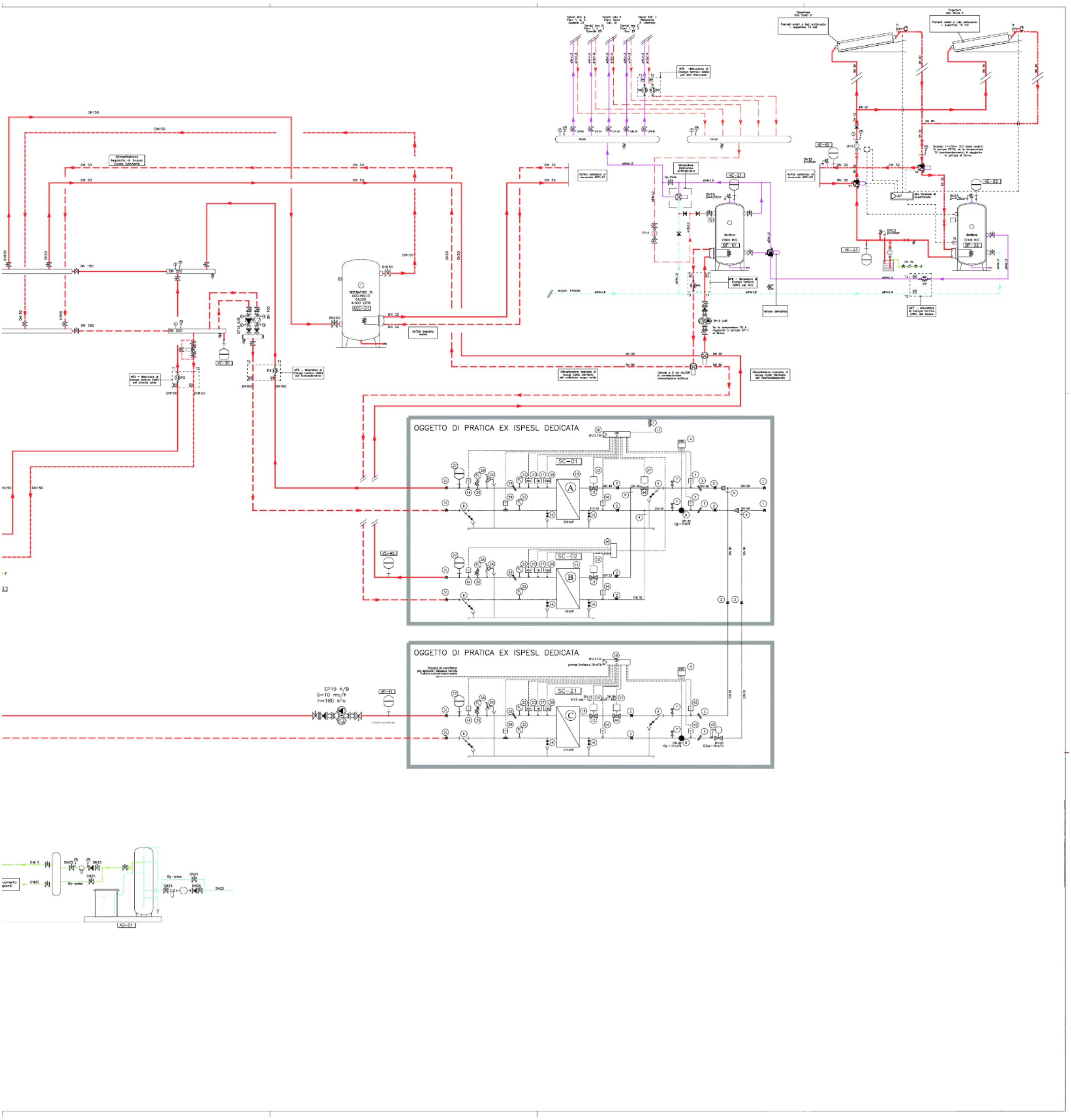


Figure 5-8 System diagram part B

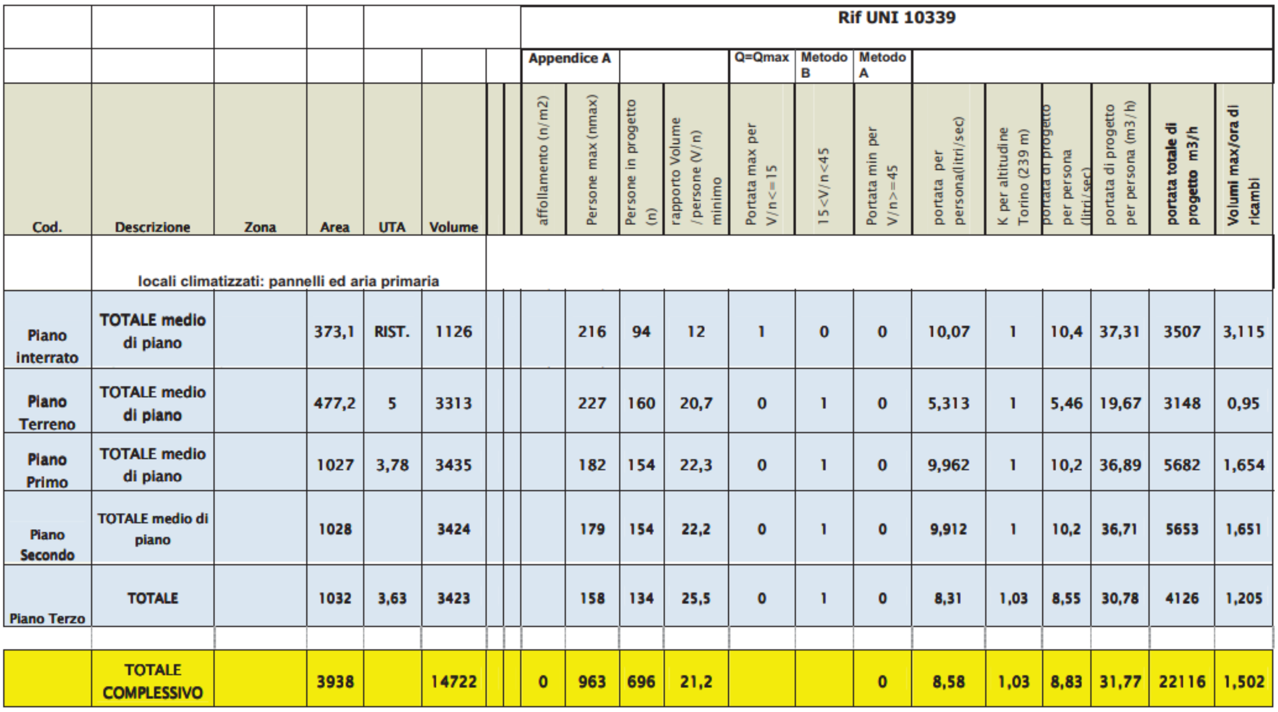
7. Accumulation of heat

10. DH heat exchanger - Absorption chiller

8.	DH heat exchanger - Heating	**11.**	Sanitary boiler
9.	DHW - DHW exchanger	**12.**	Solar thermal storage

The table 5-8 is extracted from [23]shows the design characteristics following the regulations in force.

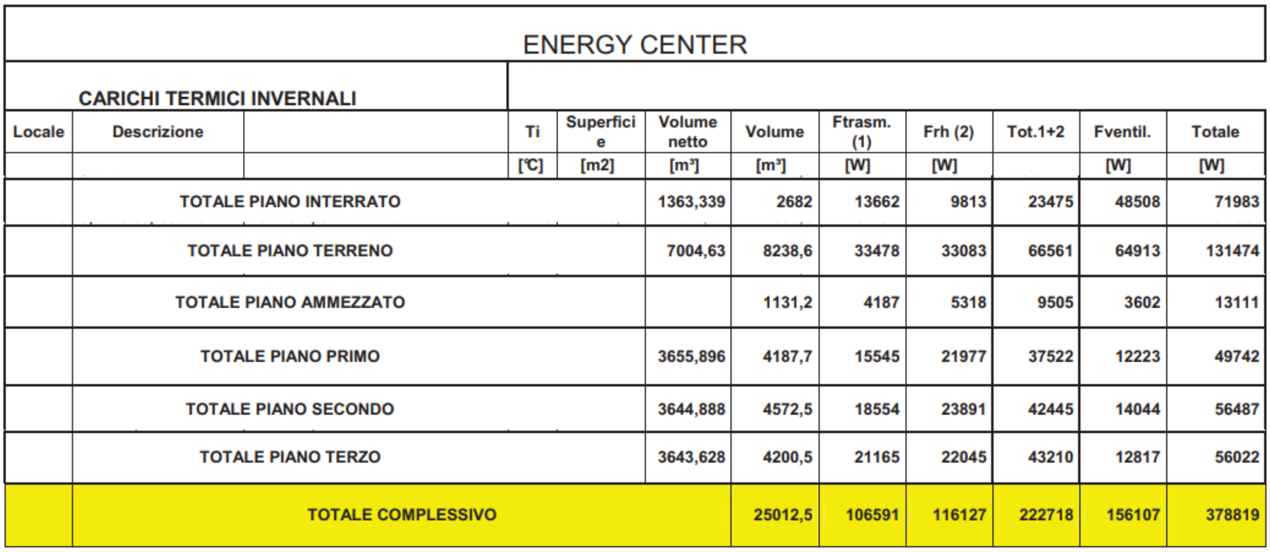
Table 5-8 Technical characteristics of the building



								Rif UNI 10339												
								Appendice A				**Q=Qmax**	**Metodo B**	**Metodo A**						
Cod.	**Descrizione**	**Zona**	**Area**	**UTA**	**Volume**			affollamento (n/m2)	Persone max (nmax)	Persone in progetto (n)	rapporto Volume /persone (V/n) minimo	Portata max per V/n<=15	15<V/n<45	Portata min per V/n>=45	portata per persona(litri/sec)	K per altitudine Torino (239 m)	portata di progetto per persona (litri/sec)	portata di progetto per persona (m3/h)	**portata totale di progetto m3/h**	**Volumi max/ora di ricambi**
	locali climatizzati: pannelli ed aria primaria																			
Piano Interrato	**TOTALE medio di piano**		**373,1**	**RIST.**	**1126**				**216**	**94**	**12**	**1**	**0**	**0**	**10,07**	**1**	**10,4**	**37,31**	**3507**	**3,115**
Piano Terreno	**TOTALE medio di piano**		**477,2**	**5**	**3313**				**227**	**160**	**20,7**	**0**	**1**	**0**	**5,313**	**1**	**5,46**	**19,67**	**3148**	**0,95**
Piano Primo	**TOTALE medio di piano**		**1027**	**3,78**	**3435**				**182**	**154**	**22,3**	**0**	**1**	**0**	**9,962**	**1**	**10,2**	**36,89**	**5682**	**1,654**
Piano Secondo	**TOTALE medio di piano**		**1028**		**3424**				**179**	**154**	**22,2**	**0**	**1**	**0**	**9,912**	**1**	**10,2**	**36,71**	**5653**	**1,651**
Piano Terzo	**TOTALE**		**1032**	**3,63**	**3423**				**158**	**134**	**25,5**	**0**	**1**	**0**	**8,31**	**1,03**	**8,55**	**30,78**	**4126**	**1,205**
	TOTALE COMPLESSIVO		**3938**		**14722**			**0**	**963**	**696**	**21,2**			**0**	**8,58**	**1,03**	**8,83**	**31,77**	**22116**	**1,502**

The table 5-9 below is extracted from [23]shows the thermal load of each floor.

Table 5-9 Energy sizing of the building



ENERGY CENTER

CARICHI TERMICI INVERNALI

Locale	Descrizione		Ti	Superficie	Volume netto	Volume	Ftrasm. (1)	Frh (2)	Tot.1+2	Fventil.	Totale
			[℃]	[m2]	[m^3]	[m^3]	[W]	[W]		[W]	[W]
	TOTALE PIANO INTERRATO				1363,339	2682	13662	9813	23475	48508	71983
	TOTALE PIANO TERRENO				7004,63	8238,6	33478	33083	66561	64913	131474
	TOTALE PIANO AMMEZZATO					1131,2	4187	5318	9505	3602	13111
	TOTALE PIANO PRIMO				3655,896	4187,7	15545	21977	37522	12223	49742
	TOTALE PIANO SECONDO				3644,888	4572,5	18554	23891	42445	14044	56487
	TOTALE PIANO TERZO				3643,628	4200,5	21165	22045	43210	12817	56022
	TOTALE COMPLESSIVO					25012,5	106591	116127	222718	156107	378819

5.3 Summer air conditioning

From project information they say that the cooling takes place through the generation of cold fluid supplied thanks to the combination of two heat pumps, namely the polyvalent group and the absorption refrigeration unit. The absorption chiller unit emits cold fluid using district heating fluid as a heat source, while the polyvalent unit generates cold fluid using groundwater as a cold source. The multipurpose unit produces a cooling capacity of 442 kW with a constant COP of 6, while the absorption refrigeration unit generates a nominal power of 155 kW with a COP of 0.76.

5.3.1 Absorption refrigeration unit

The gas absorption refrigerator is a refrigerator that uses a heat source to rotate its refrigeration cycle, allowing heat to be extracted. This process replaces the compressor normally used. This mode of operation is used when electricity is not readily available (too scarce, too expensive, difficult to produce, for example in a camper) , or when there is a practically free heat source (strong sunlight, gas or hot liquid from a turbine or industrial process, etc.).[24]

In summer air conditioning, despite having an absorption refrigeration unit, it is not used at all as even the district heating network does not have enough heat to satisfy the energy demand. To try to explain the reason behind not getting enough heat, it is necessary to analyze how electricity is produced [36]

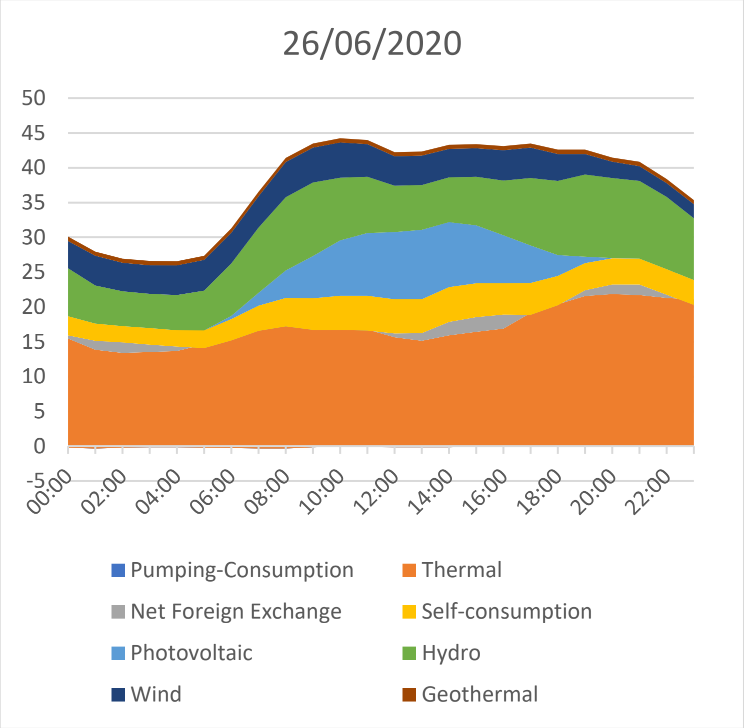


Figure 5-9 summer 2020 electric mix

The graphs above shows the electricity production on a summer day. As you can see, electricity production is still abundant and constant throughout the day; however, the demand for thermal energy in the summer is low so obviously there will be few power plants that decide to sell thermal energy in the summer. The final result is therefore the perpetually off absorption refrigeration unit [36].

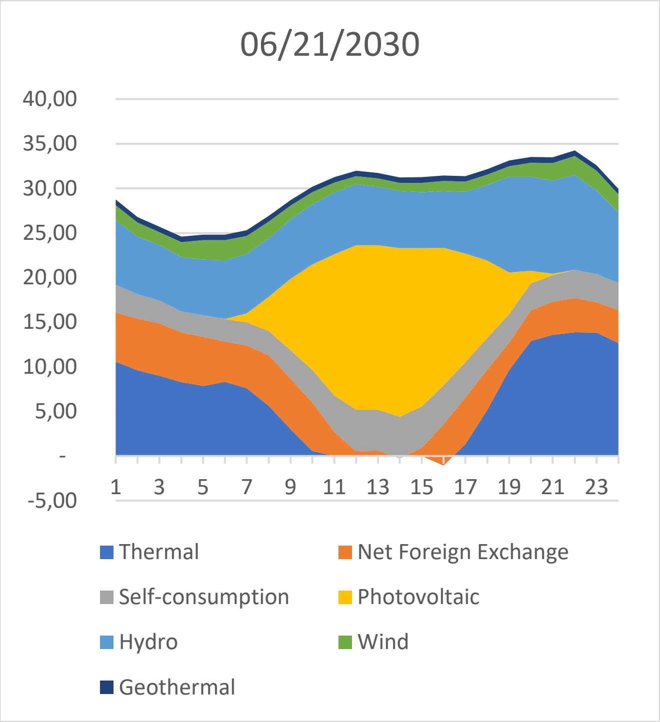


Figure 5-11 summer 2030 electric mix

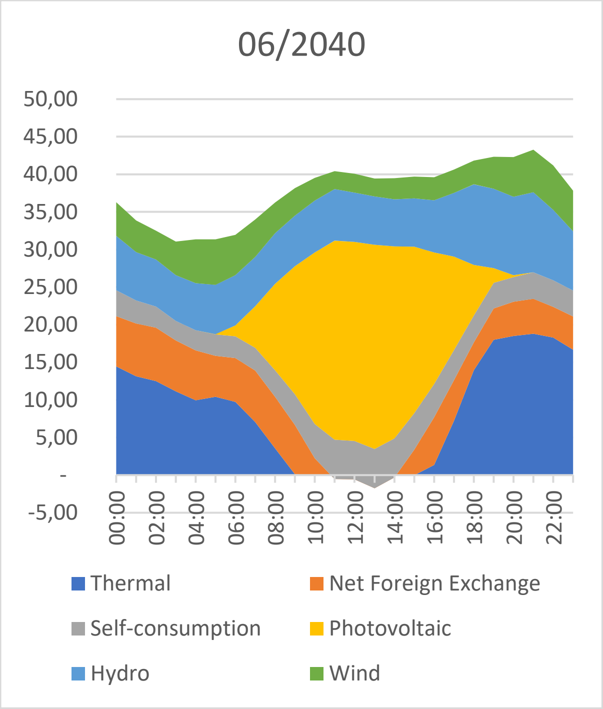


Figure 5-10 summer 2040 electric mix

It is important to note that according to the study carried out in the previous chapters, although the absorption refrigeration unit shows potential in 2020, it completely loses sense in the future summer scenarios of 2030 and 2040 as the production of electricity in the central hours of the day is null and consequently the district heating network is unable to recharge.

5.3.2 Multi-purpose refrigeration unit

The multi-purpose refrigeration unit is based on the refrigeration cycle; it is an inverse thermodynamic cycle performed by an operating machine capable of transferring heat from a low temperature environment to a higher temperature one.

In the energy center he is solely responsible for heating the building. It uses groundwater as a hot spring and has a COP of 4.54 and a TER of 5.98. It produces both cold and hot fluid at the same time. The hot fluid is accumulated, used for DHW, used as post heating in the AHU and expelled when overproduced. Similarly, the cold fluid is used to cool the building and dehumidify the air in the AHU in order to reach and stay in the comfort temperature and humidity.

To analyze the air conditioning, the thermal power detectors placed near the refrigeration unit were used. From those values, an average of the values was carried out for each month in such a way as to have on the side of the abscissas the hours of the average day net of working days, while on the ordinates we have the average cooling power released according to the time of day . The result of this average consists of two graphs, the first is part and refers to the production of cold fluid for cooling the building and dehumidification of the environment, while the second graph represents the heated fluid for post heating.

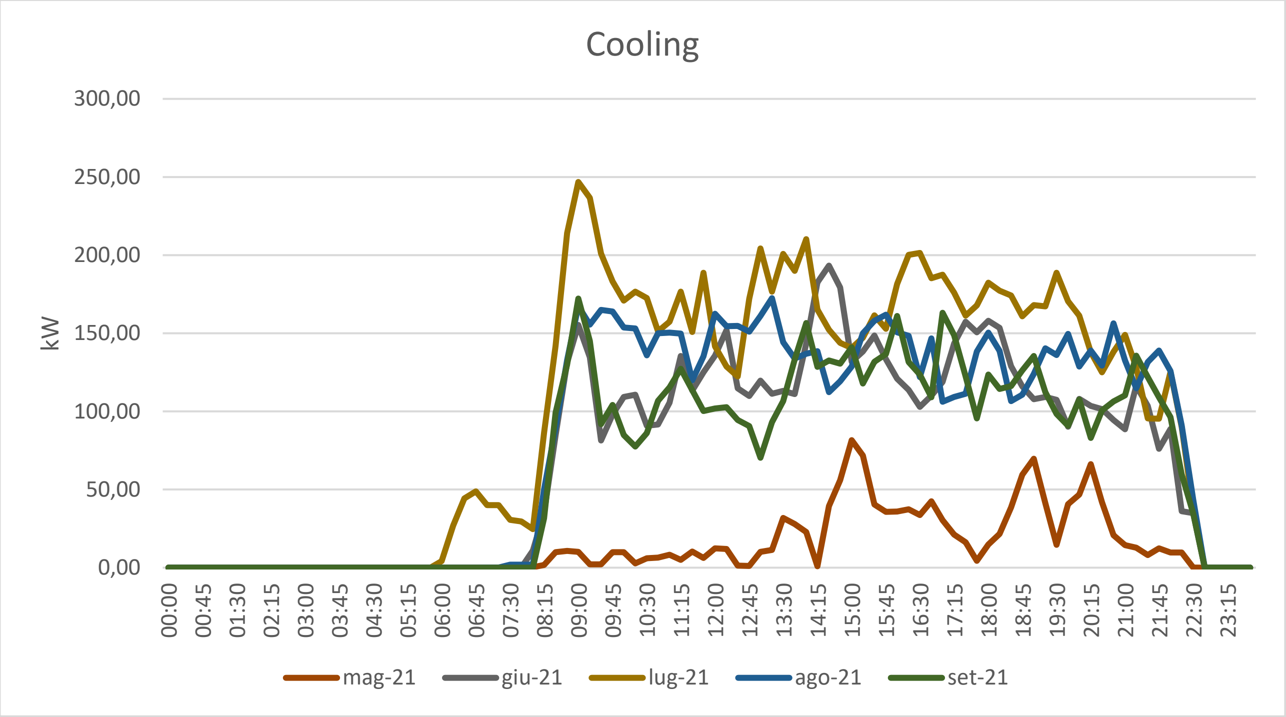


Figure 5-12 Cold production

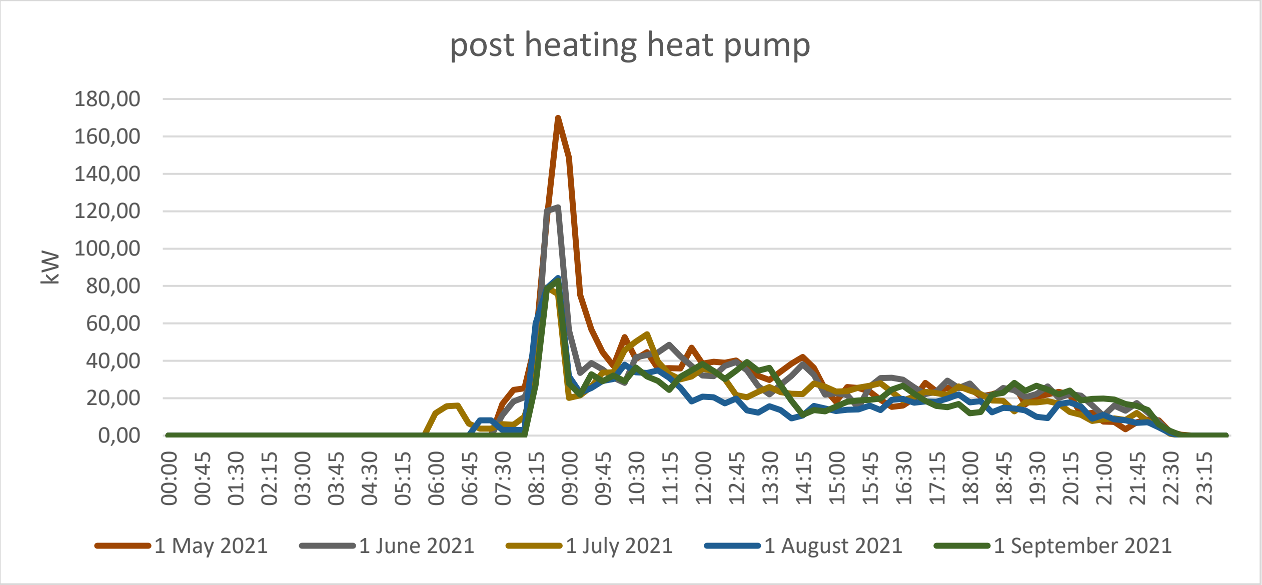


Figure 5-13 Hot production

The first impression that comes out of these graphs is that they are very messy and do not seem to have a continuity over time but on the contrary seems to be subject to continuous transients. The assumptions that the graph seems very discontinuous can be justified by:

- Continuous thermal transients: The machine turns on and off very frequently
- Inaccurate thermal readings

However, it was possible to identify and study a classic typical day to have a comparison with the analyzed values. These values are extracted from stocks of the Polytechnic of Turin [35]

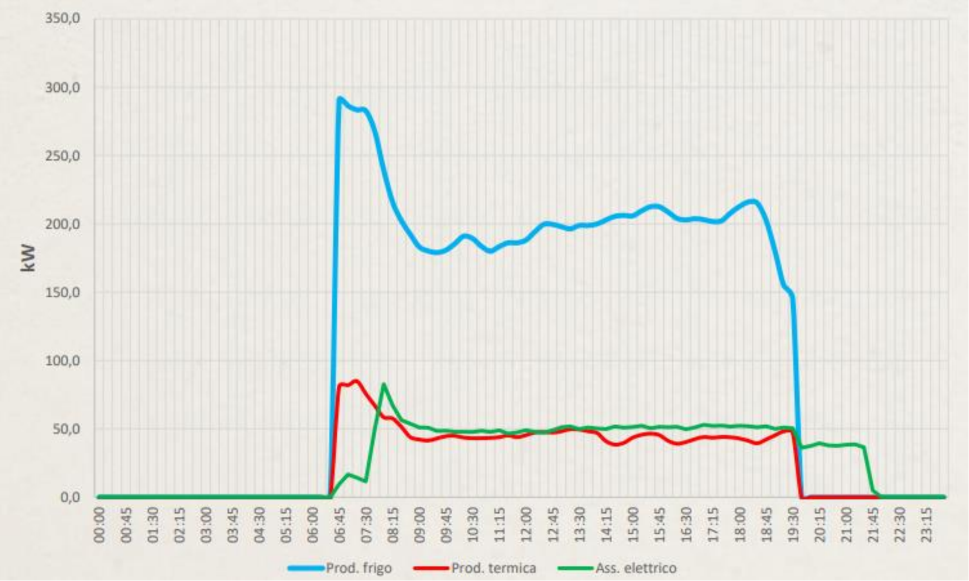


Figure 5-14 How summer air conditioning should work

The blue curve corresponds to the cold thermal energy used to cool the building, the red curve represents the thermal energy produced, while the green curve represents the electrical energy used to generate and transport a cold and a hot flow.

Now, the values studied in the month of July are analyzed in the graph belove shown in figure 5-15 is the typical day.

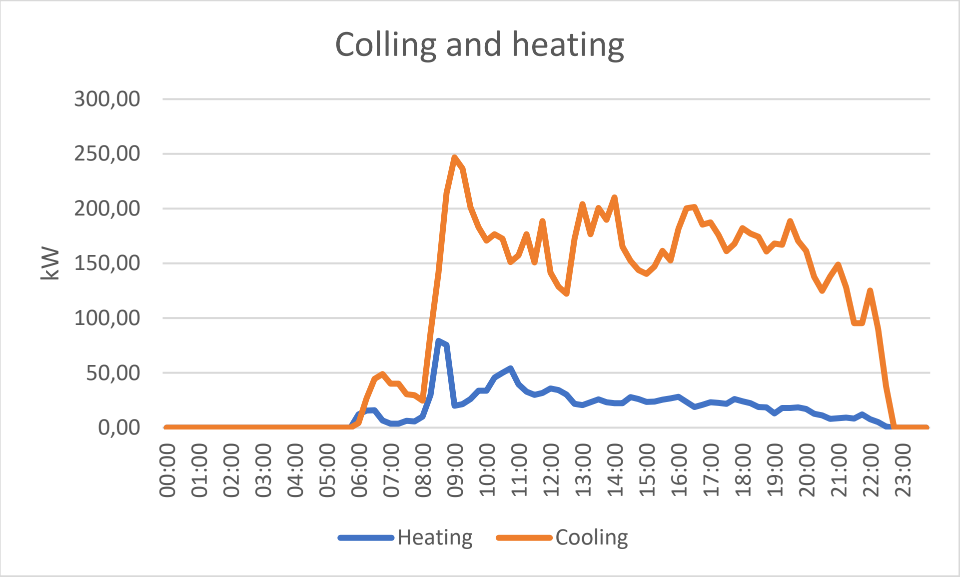


Figure 5-15 How summer air conditioning works

From the comparison of the graphs it can be seen that the values are similar, however there are important differences on the continuity of the curves and on the switching on and off times of the air conditioning system as in the analyzed values it seems that the system is switched off at 10 pm instead of at 19.30 while the start of air conditioning seems to be carried out with DSM in such a way as to reduce the energy peak at 6.30 and have an energy peak at around 9 of 250 kW instead of 300 kW as the diagram shown on the polytechnic stock.

5.4 Winter heating

The heat requirement of the energy center is largely supplied by a district heating network which alone almost entirely satisfies the annual thermal energy requirement in the winter months. However, the heating structure is more complex than one might think as it is coupled to a multipurpose heat pump that simultaneously generates both hot water (which will contribute to the heat requirement) and cold water that will fill a cold water storage but given the low demand in the winter season it will be discharged into the groundwater.

The exchanger connected to the district heating network is a heat exchanger and can exchange up to a power of 350 kW, while the multipurpose unit manages to generate a thermal power of 474 kW with an almost constant COP 4.58.

The theoretical warming studied by researchers before me suggests this trend [35]:

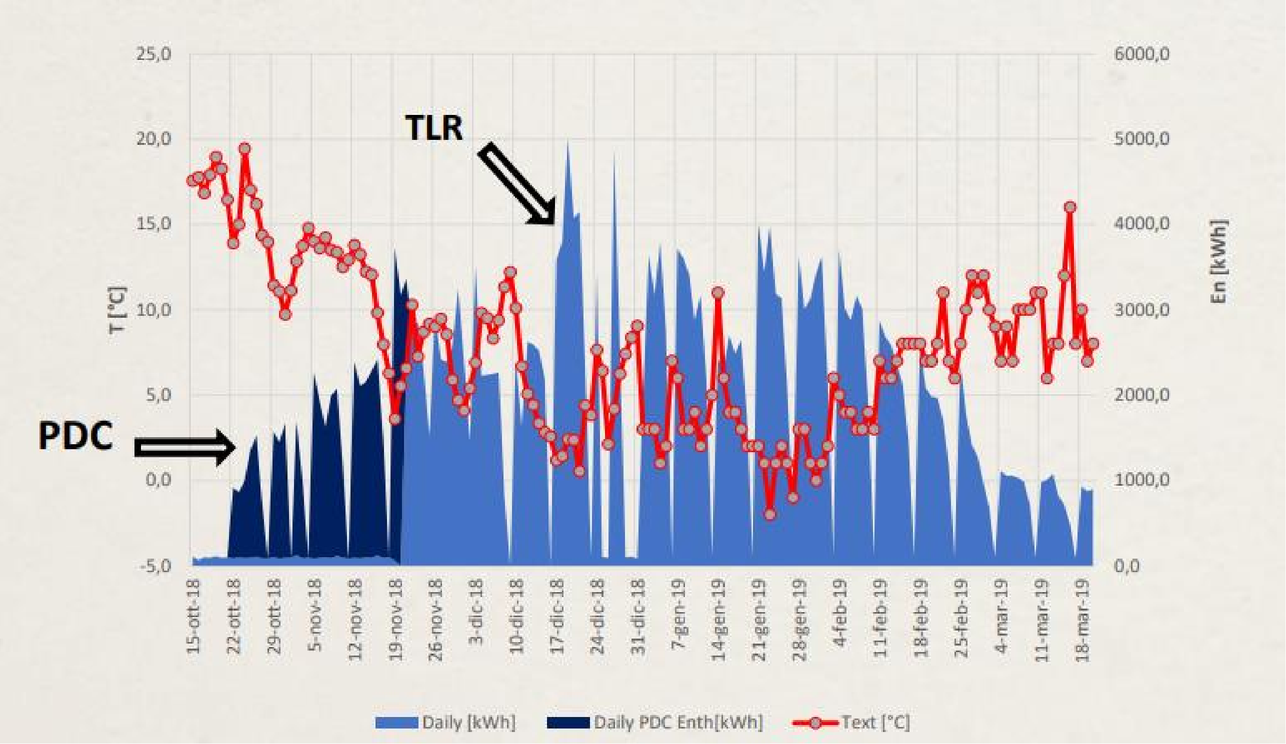


Figure 5-16 How winter heating should work

The graph shows the power required by the system in the days ranging from 15 October 2018 to 29 March 2019, it can be seen that the heat produced from the beginning of operation to 19 November 2018 is completely satisfied by the heat pump, while from 19 November 2018 until the end of the season the heating is entirely supplied by the heat pump.

In the following paragraphs the trends of the winter 2020/2021 will be studied

5.4.1 Multipurpose unit operating in heat pump

Unlike the figure 5-16 in the initial project. The multipurpose heat pump is not used at all for heating in the winter. For this reason, there is no data and it can only be assumed that it was not economically sustainable.

5.4.2 District heating

District heating is a form of heating which consists in the distribution through networks of insulated pipes (mostly underground) of hot, superheated water or steam (called heat transfer fluid), coming from a large production plant. With this system, the water reaches the homes by operating in the heating or cooling systems, and subsequently returns to the same plant at a lower or higher temperature.[25]

The heat exchanger installed inside is a compact water / water plate heat exchanger. The nominal power of the heat exchanger is 350 kW. The following graph shows the average values of the period under examination.

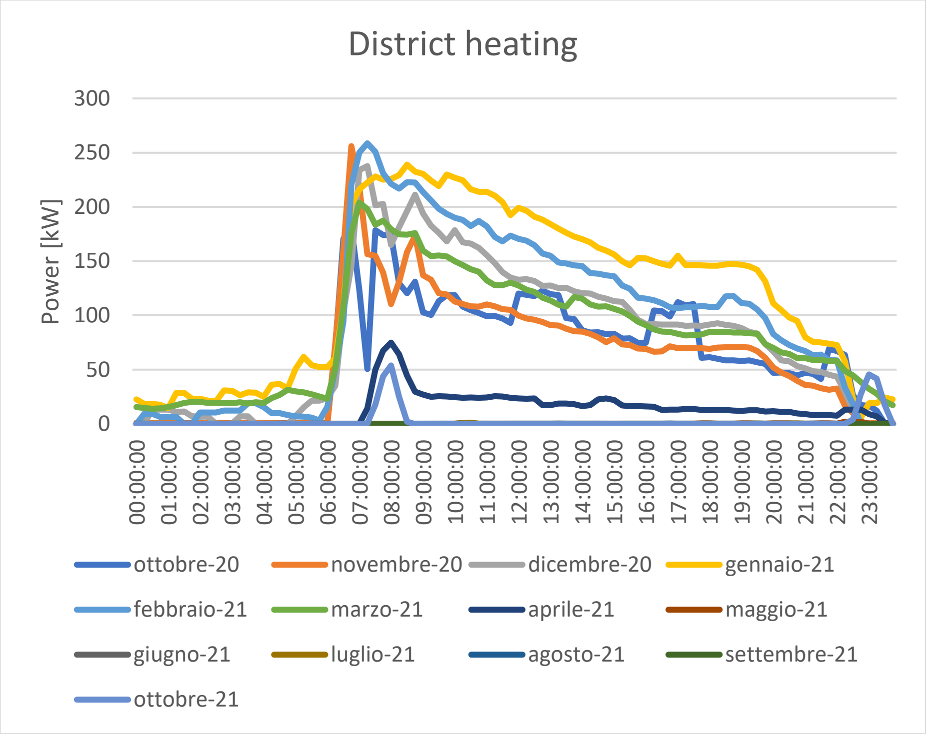


Figure 5-17 How winter heating works

The graph shows the average values of the heating power net of weekdays. You can see the warming peaks in the morning around 7:30 am and that for all months except January and March there is no DSM. As in the case of the heat pump, here too the operation of district heating is different from that studied in the winter of 2018/2019

The figure 5-18 below [36] shows how, in the current periods there is not only a large electricity production from ditch fuels but also a great continuity during the day, so consequently there is also a very high potential for cogeneration and given its continuity, to the moment seems very reliable in the wintertime.

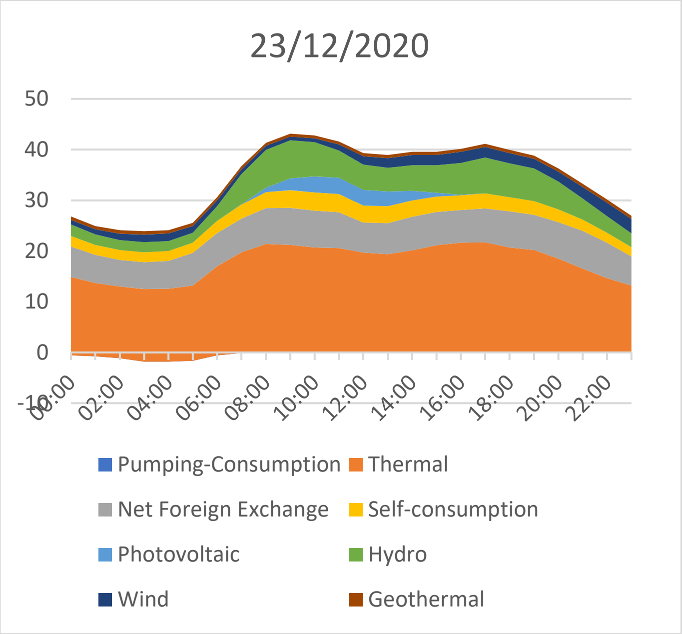


Figure 5-18 Winter 2020 energy mix

The multipurpose group on the contrary

5.4.2.1 Situation in 2030

It is expected that in 2030 the district heating network will continue to operate at full speed as according to the figures, the thermal energy produced in 2020 is expected to be similar to that produced in 2030

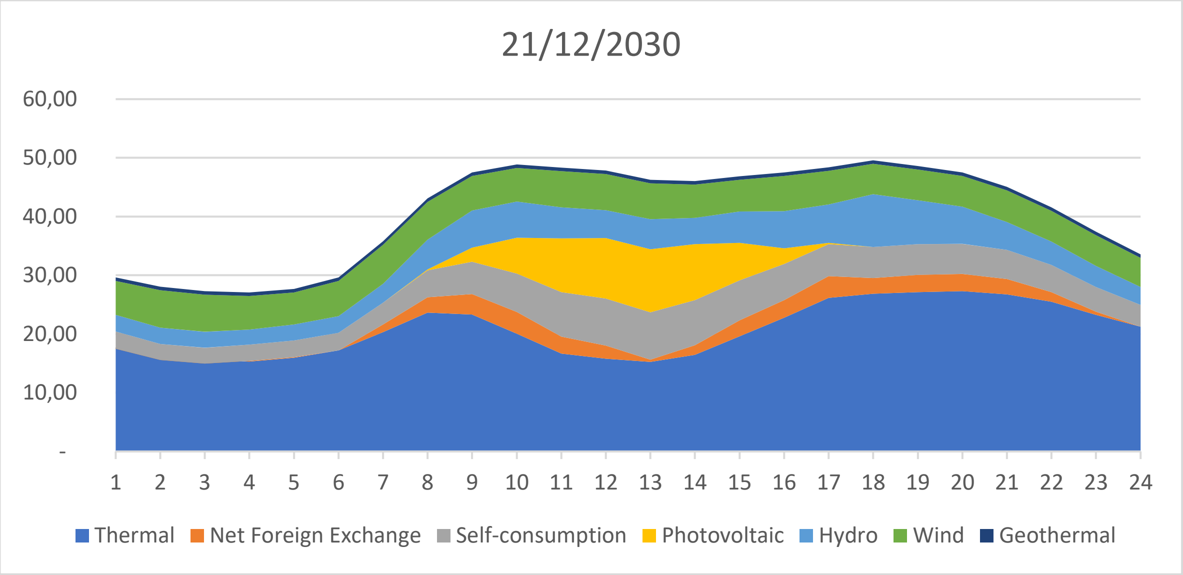


Figure 5-19 Winter 2030 energy mix

5.4.2.2 Situation in 2040

The study carried out predicts that in 2040 the district heating network will continue to operate at full speed as according to figures, the thermal energy produced in 2040 is expected to be similar to that produced in 2020.

However, even if the quantity of daily thermal energy is similar, it is expected that the role of the DSM will be very important since in the central hours of the day the production of energy supplied to the district heating network by the thermal plants will be much less; therefore, a good DSM strategy is based on making the best use of thermal energy when abundant.

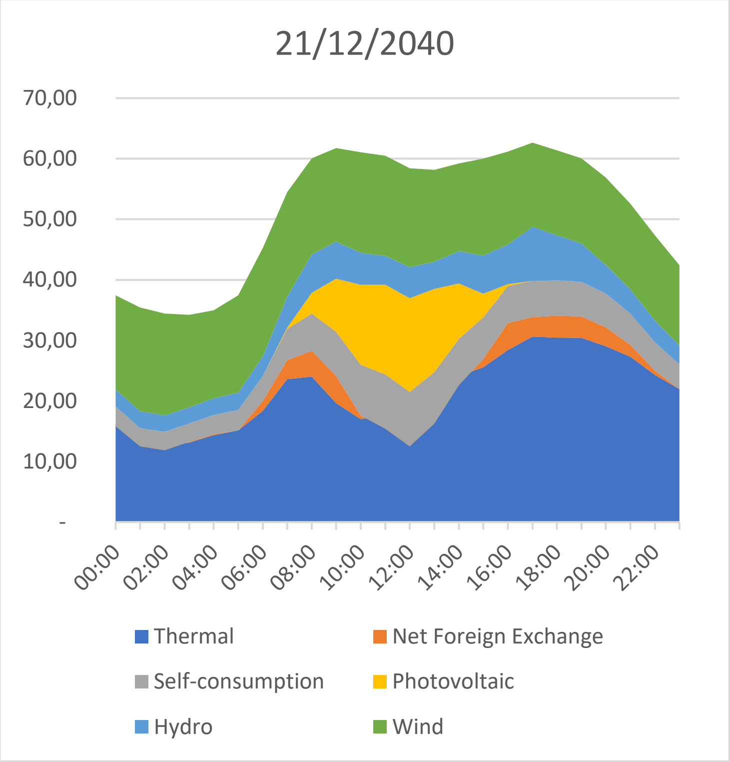


Figure 5-20 Winter 2040 energy mix

5.5 DHW Domestic Hot Water

The domestic hot water in the Energy Center is structured in such a way that it is always guaranteed. In fact , it is supplied through three different systems for the production of heat: Solar contraction panels, district heating and electrical resistance inside the thermal storage (which can only be activated in the absence of other sources available). The solar contraction panels have a total of 30 m2 of exposed surface, to reach the daily requirement, in fact, they are coupled with a heat exchanger connected to the district heating network that produces a thermal power of 50 kW. The energy sources manage two water networks with three boilers of size from 1 to 4 m3 which are connected to each other by a simple 3-way branch.

There remains a shadow of uncertainty about what feeds the DHW network as it seems very underestimated that it cannot even be counted. The figure 5.21 shows the power required by the DHW during the day

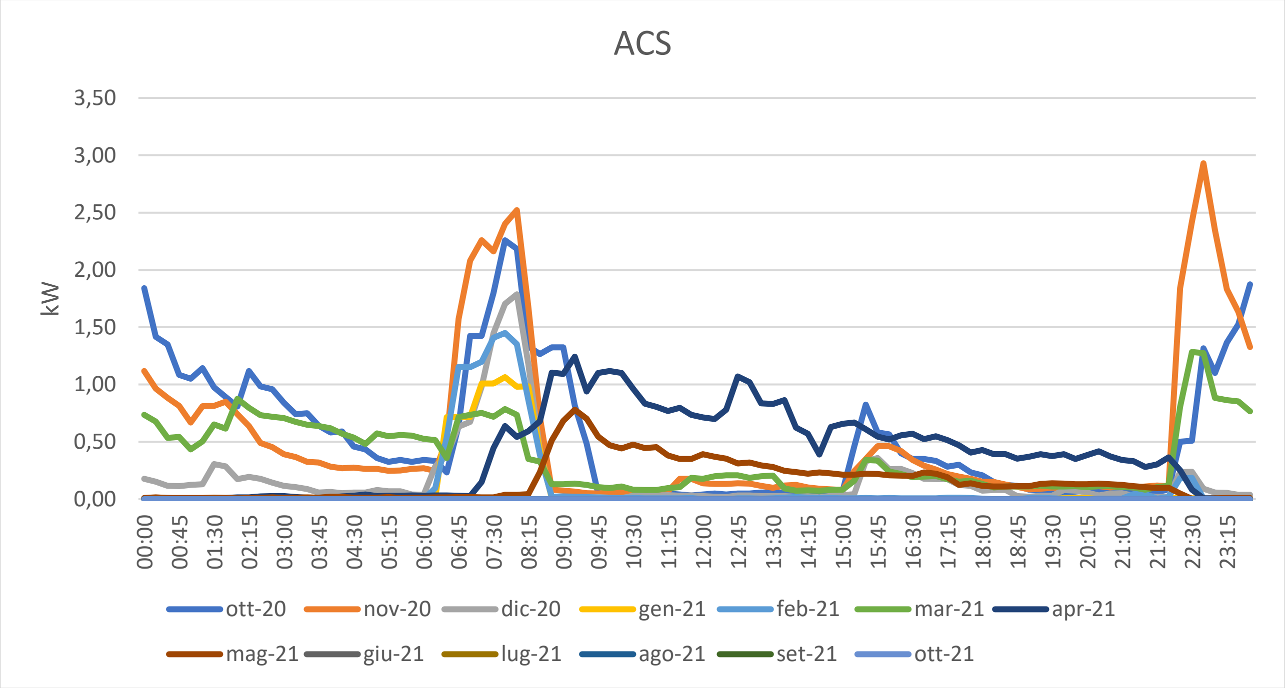


Figure 5-21 DHW operation from district heating

6. Implementations through the DSM

DSM solutions rely on both observation and monitoring. So first of all, to get a good idea about the DSM proposals it is necessary to improve the data provided to the students from the monitoring point of view. This criticism emerges because several times in this study it has happened to clash on the false truthfulness of values such as, for example, the photovoltaic production of the scale group A, the relative power values of the district heating plant and of the multipurpose group. To complicate the situation there was also the scarcity of data as it was not possible to have the electricity consumption of the multipurpose group and the seasonal consumption of thermal energy from the district heating network.

However, studying the data collected, I was happy to note that the energy center already implements a DSM strategy. The figure 6-1 shows the comparison between the average day in January and the average day in February. From this analysis it can be seen that the strategy works because as explained in the table 6-1, the maximum peak of energy demand is not reached from the month of January (although this is the coldest month) but from the month of February as in January it is load shifting strategy was applied.

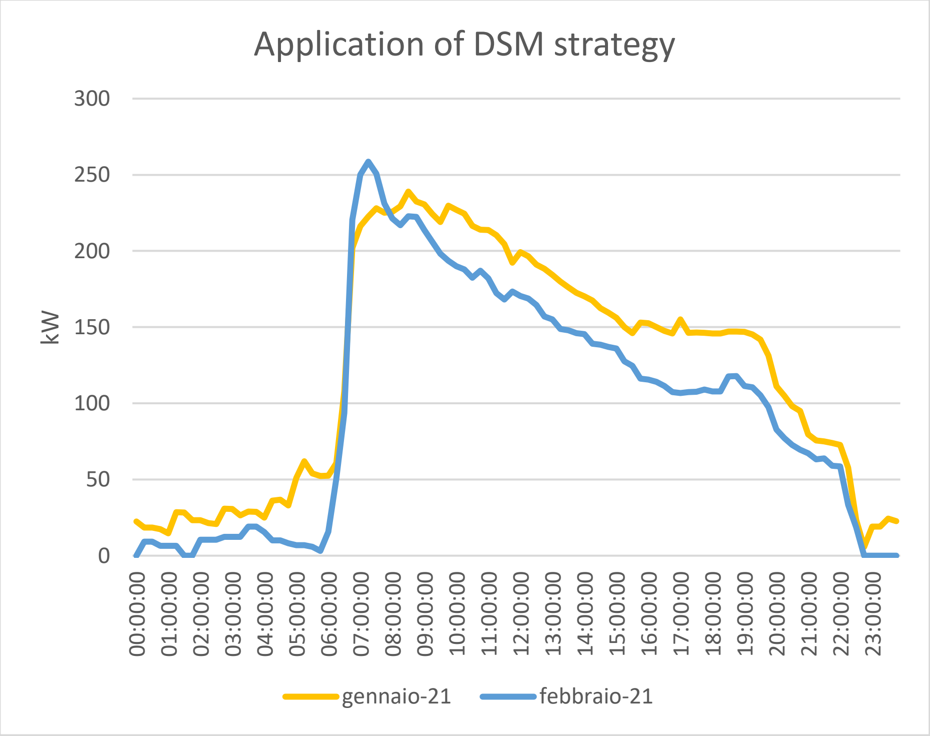


Figure 6-1 Application of DSM strategy

Table 6-1

	Energy consumed [kWh]	Peak energy [kW]
January	2909	239
February	2366	259

Once DSM was measured to work, they were investigated in the next two experimental applications of DSM.

6.1 DSM strategy on summer air conditioning

Studying the summer air conditioning in the Energy Center, you immediately notice that the climatic conditions in the summer season are: Internal temperature of 26 °C, relative humidity 50%.

This strategy is based on the principle of strategic conservation .

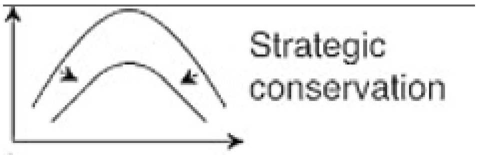


Figure 6-2 Strategic conservation

In this case the strategy is based on a change in the air conditioning strategy.

As explained above, a large part of the cooling of the building takes place thanks to AHU, while in the areas covered by the AHU, a forced ventilation system is however provided. The AHU is the organ for controlling the air conditioning, it performs the cooling, dehumidification of the air and the post heating. The graph below shows the power as a function over time on a typical June day.

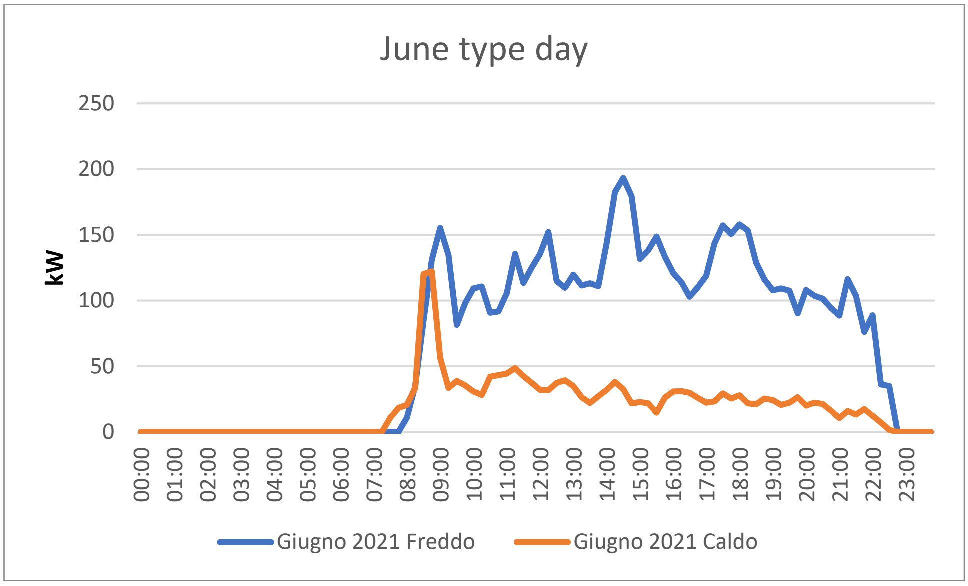


Figure 6-3 How summer air conditioning works

However, as shown in the figure, studying the air conditioning of two classic typical days of June, it is noted that the temperatures and the comfort humidity are not so far from the external temperature and humidity.

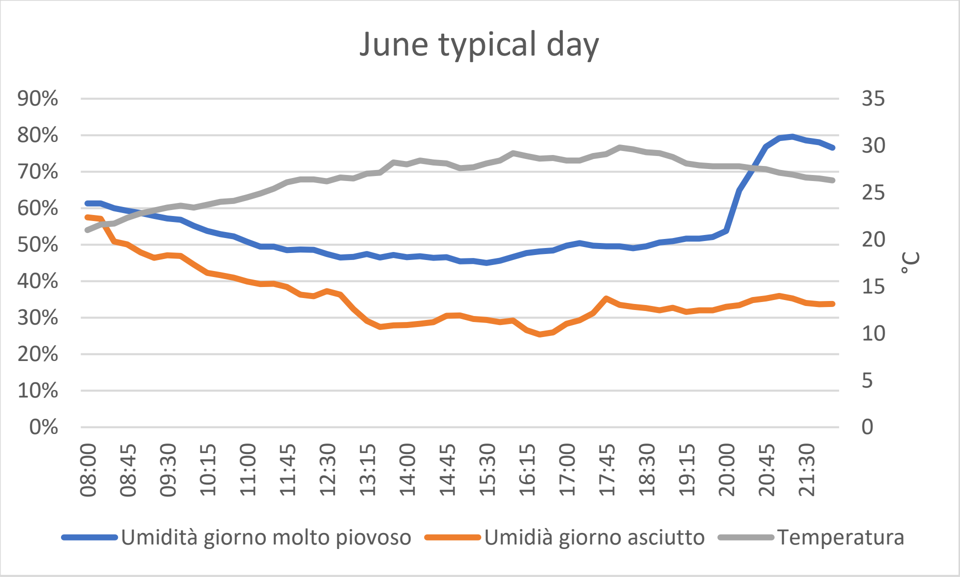


Figure 6-4 External weather situation

This strategy is based on the principle that the typical days of a month can be very different from the hottest days of the month so their cooling can be managed with a completely different strategy. The DSM strategy in this case would only be used in case of average temperatures and humidity.

So the new strategy will use only mechanical ventilation a lot, much less the cooling coil and will not use the post heating coil at all.

To make an analysis of the critical points of the new strategy it is necessary to look at the graph. It can be noted that:

- In conditions where the temperature is less than 25 °C and the humidity is between 40% and 60%, only ventilation is always checked.
- For very low humidity values with very high temperatures, sensitive cooling or possible adiabatic humidification are sufficient to guarantee comfort
- For relative humidity and temperature values above or within the comfort values, the strategy is not verified and require the forced control of temperature or humidity operating with:
    - Cooling and dehumidification of the air mixed with the recirculated air for temperature and humidity control
    - Cooling, dehumidification and post-heating of the internal air with possible mixing with the recirculation area

The figure 6-5 (legend is table 6-2) shows the conditions with which the state of thermal comfort is reached.

Table 6-2 legend

🟨	Sensitive cooling and post heating
🟥	Heating
🟦	Sensitive cooling
🟦	Adiabatic humification
⬜	sensitive cooling and adibatic humidification

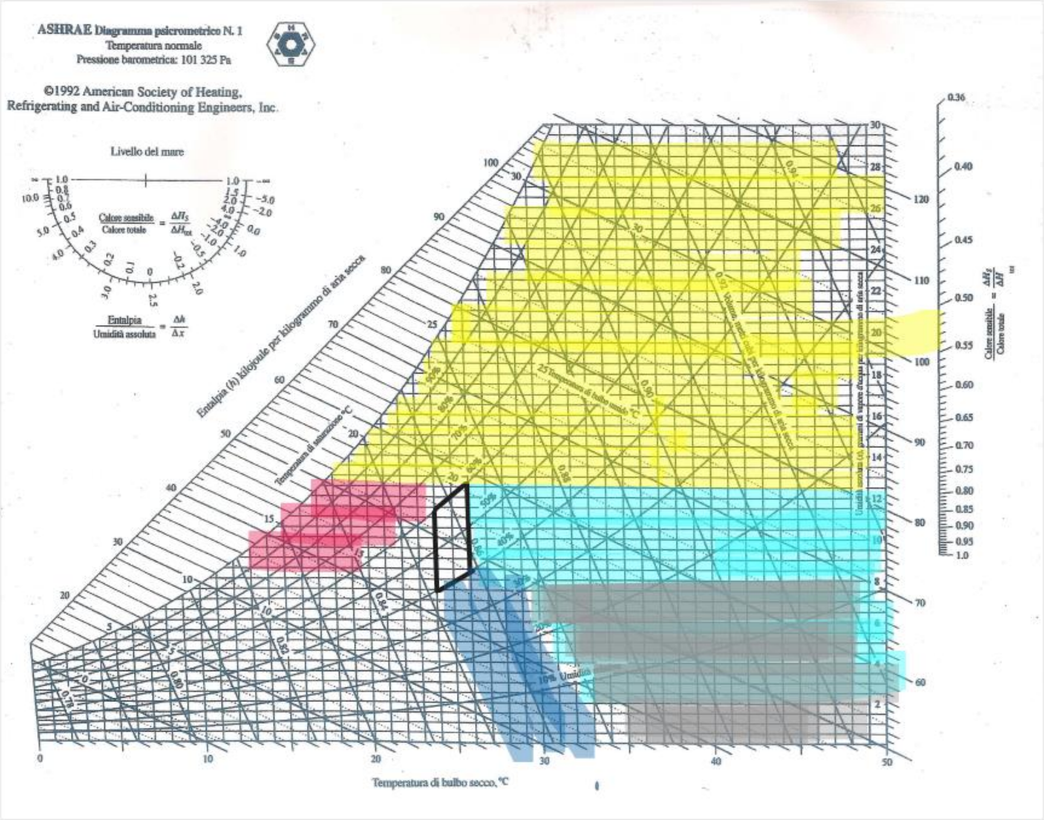


Figure 6-5 summer air conditioning strategy

To get an idea of energy saving, the typical trend of the DSM is shown next to the cold only coil of the refrigeration pump

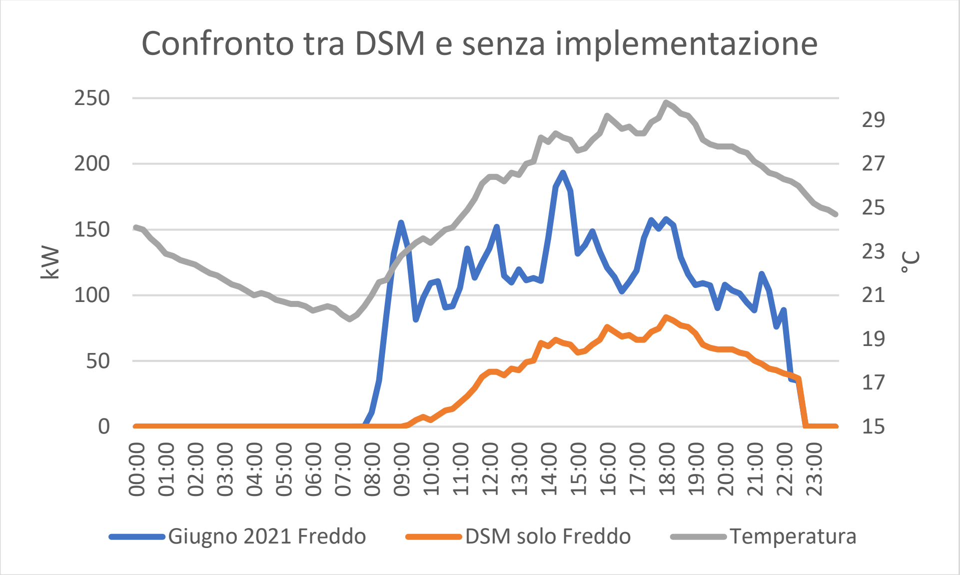


Figure 6-6 DSM strategy application

Figure 6-6 shows a huge difference between actual thermal energy consumption and daily thermal energy consumption. The first difference is precisely during the hours of ignition as the ignition takes place at 8:30 in the morning when the outside temperature is still around 22 ° C while the DSM strategy starts the ignition gradually around 10:00 when the temperature exceeds 23 ° C (as it takes into account the internal and solar thermal contributions). The biggest difference with the DSM strategy compared to traditional operation is that post-heating never takes place for humidity control. However, if the external conditions respect average monthly values of humidity and temperature, the comfort does not need post-heating as the internal humidity would automatically be between 40% and 60%. The following table shows the savings between the calculated average day and the measured average consumption. The savings correspond to about 55% of thermal energy.

Table 6-3 DSM strategy application

Thermal consumption [kWh]	DSM consumption [kWh]	Savings
1693	749	55%

6.1.1 Summer DSM strategy comments

After DSM strategy for summer, it is necessary to comment on the current functioning.

Taking the hottest days of the month as a reference day as shown in the figure, it can be seen that the cold thermal energy used is very similar to the thermal energy required as shown in the table. In addition, it should also be noted that the comfort conditions on hot days can only be achieved thanks to post-heating for humidity control. The operation of the Energy Center on very hot days is therefore very similar to perfection.

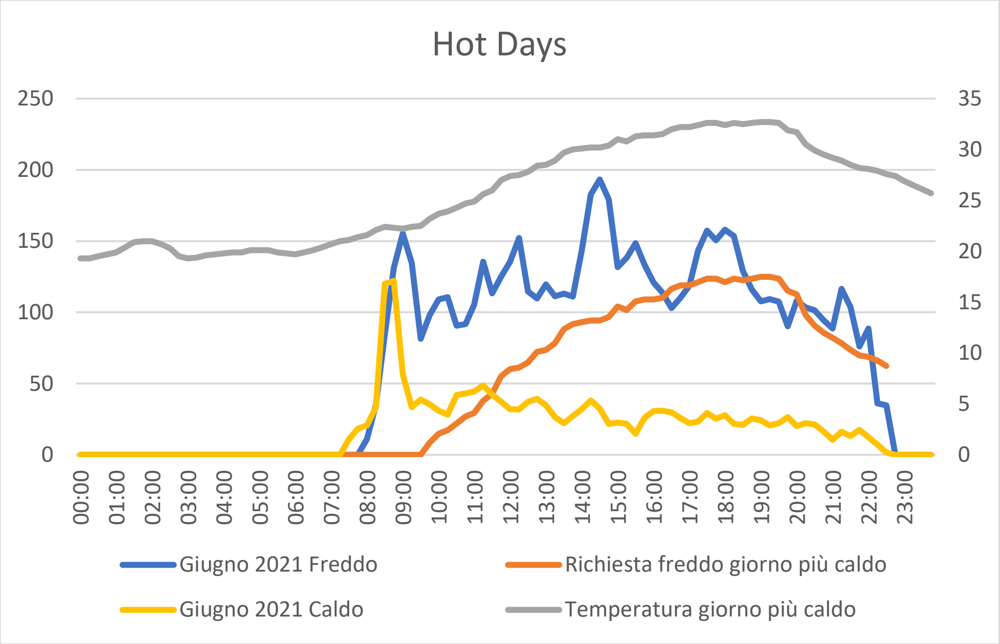


Figure 6-7 Limits of DSM strategy

Table 6-4 Limits of DSM strategy

Cold energy produced [kWh]	Hot energy produced [kWh]	Cold energy provided [kWh]	theoretical consumption required [kW]
1693	561	1235	1114

However, this operation is only suitable for very hot climatic conditions where there is not only a high external temperature but also high solar inputs. Getting to provide the comfort temperature is very difficult as you have to take into account identical zones which unfortunately need a different and specific cooling. Temperature sensors are excellent for providing the right thermal load, however their operation is very often compromised by people and consequently the system will malfunction.

So the current DSM strategy for summer cooling has two major limitations. The first is that it can only be applied on standard days the peak temperature is below 28.5 C and the outdoor humidity is between 30% and 50%.

The second limitation is the good management of the cooling system by the users. This part is very important as bad management could cause the temperature sensors to malfunction, resulting in a state of comfort that is worse than the state of comfort that would occur without conditioning.

6.2 Winter air conditioning strategy

In the previous chapters we could see that the district heating network does not have unlimited power and that sooner or later it will reach a saturation point or the point in the power supplied by the district heating network will not be enough to provide the rated power to all buildings. during peak demand hours. This section talks about how to deal with the problem once this value is reached.

This time the strategy used is Load shifting . This strategy is based on the principle of lowering the energy demand during peak hours, while raising the demand during peak and minimum demand hours.

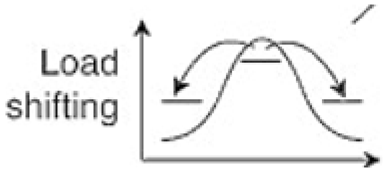


Figure 6-8 Load shifting

The study carried out with the DSM therefore wants to emphasize the limits of this strategy to show the strengths and weaknesses of the strategy.

The chart below shows the warming in February without the DSM strategy in orange and with the DSM strategy in blue. The graph shows that the load has shifted from peak time to two hours before peak time. This advance would allow the district heating network to lighten and therefore at peak times it will not have to withstand a peak of 250 kW but of 150 kW.

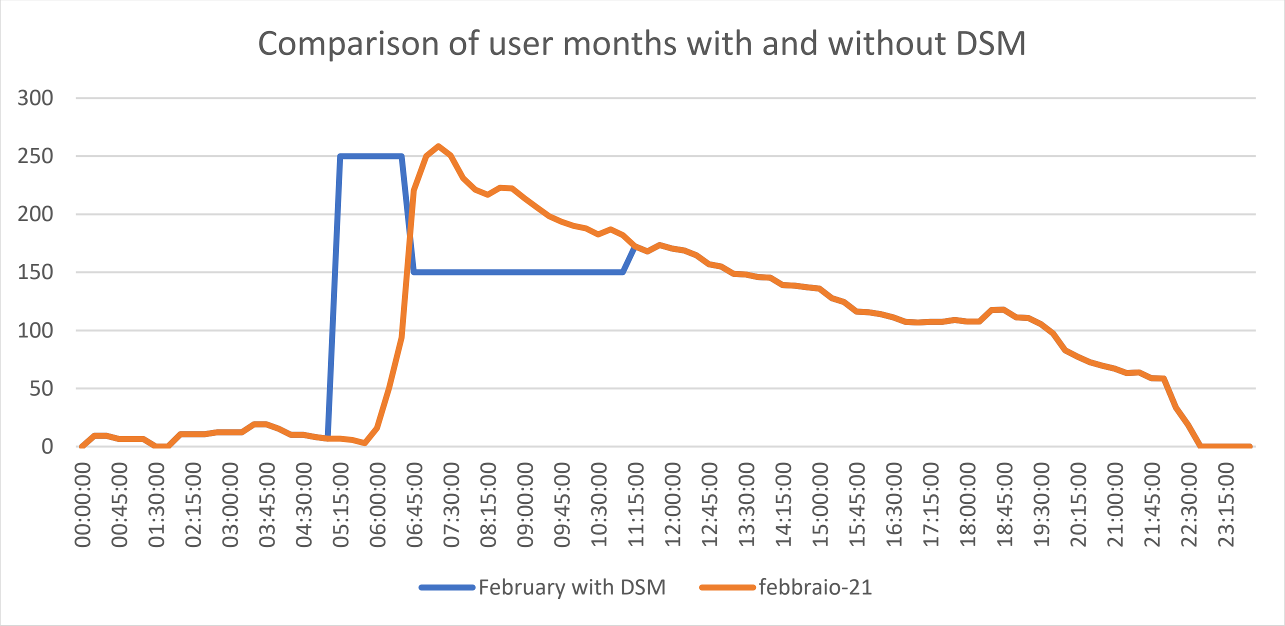


Figure 6-9 DSM strategy application

However, this strategy does not bring benefits in purely energy terms since, even if the calculation was carried out net of the ventilation required by the occupants, turning on the heating first not only inevitably leads to an increase in heat loss as the building reaches temperature earlier. , but even an additional increase in dispersions as the building must increase adiabatic humification and consequently post heating.

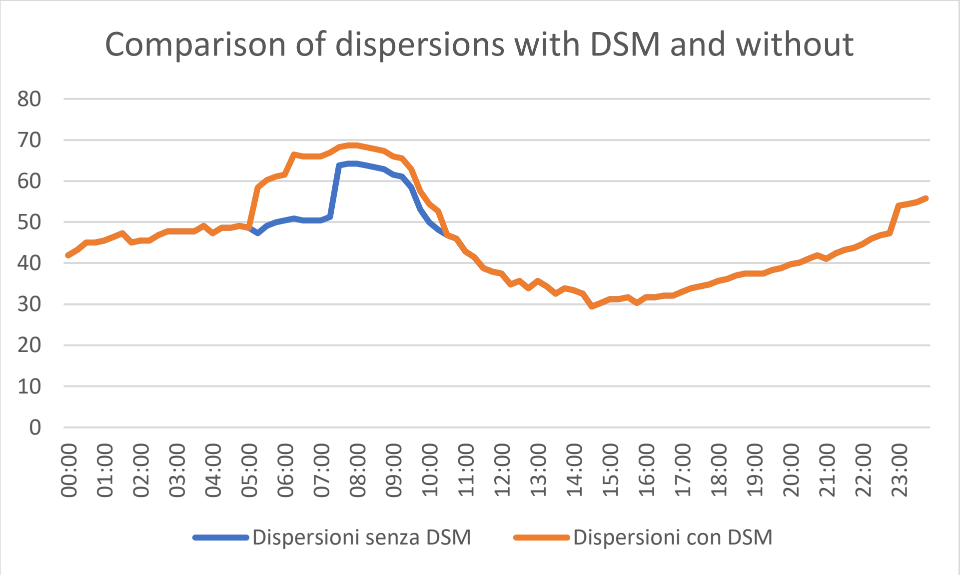


Figure 6-10 comparison between thermal dispersions before and after DSM

From the graph it can be seen that not only the dispersions due to the DSM start earlier but even last even when the DSM strategy is finished working as this strategy is calibrated to raise the internal temperature of the building by 1.5 °C compared to that required, therefore in the following hours there will still be an additional energy consumption due to the accumulated thermal latency.

The following table shows the consumption both in the case of normal use and in the case of DSM strategy.

Table 6-5 comparison between thermal dispersions before and after DSM

	Normal [kWh]	DSM [kWh]
Energy consumed from 00:00 to 06:30	44	375
Energy consumed between 06:00 and 23:59	959	675
Total	1003	1050

It is noted that the total consumption during the day is about 47 kWh which is equivalent to 4.7% of the total energy used.

However, when the grid becomes saturated it is assumed that there will be economic incentives to start heating during off-peak hours.

In the specific case of the energy center, an accurate study was carried out to assess how the DSM strategy becomes economically sustainable.

The following table shows different reference values, some referring to the consumer while others referring to the seller. Assuming that the attack on the district heating network takes place only if the network at peak times has enough power to meet the nominal needs of the building, five parameters are shown depending on each other, so we have:

- The price in the hours of minimum request: this price is supposed to go from 00:00 to 06:30. It is not defined by an absolute value but is corresponding to the percentage of the price compared to normal values
- Fixed energy center savings: Corresponds to the savings that the energy center would have without implementing the DSM as the night still requires a small part of thermal energy. On the other hand, this value is equal to the percentage that the supplier would lose if he decided to implement this favorable pricing strategy to favor the DSM and the user does not carry it out.

- Energy Center savings with DSM: corresponds to the percentage value that the energy center would actually save in economic terms
- Building attack gain 40% large than the Energy Center: it is the total gain that the energy supplier would have once the energy center implements the DSM and therefore would leave a power equal to 40% of its nominal power available
- Building attack gain 67% larger than the energy center with DSM: it is the total gain that the energy supplier would have once the energy center implements the DSM and at the same time the new building would implement a DSM policy; therefore, it would leave available a power equal to 67% of the nominal power of the energy center.

Table 6-6 Economic compromise study for the DSM

Price from 00:00 to 06:30 compared to the base price	Fixed savings Energy center	Energy Savings Center with DSM	Building attack gain large 40% of the energy center	Building attack gain 67% larger than energy center with DSM
25.0%	2.9%	11.4%	27%	48%
45.0%	2.2%	7.9%	31%	54%
60.0%	1.6%	5.2%	34%	58%
70.0%	1.2%	3.4%	36%	61%
80.0%	0.8%	1.6%	38%	64%
89.0%	0.4%	0.0%	40%	67%

The graph shows that in the specific case of the energy center, for there to be a gain, the cost of energy in the low hours required should be at least 89% compared to the base price.

From a graphical point of view it is easy to see where the gain is from the supplier to incentivize DSM policies as freeing up power in the hours of maximum demand means guaranteeing power for a second buyer. In the case studied, in fact, the energy center releases 40% of power during peak hours, this means that the seller can sell energy to a building that consumes 40% of the energy center. The figure 6-11 shows this example.

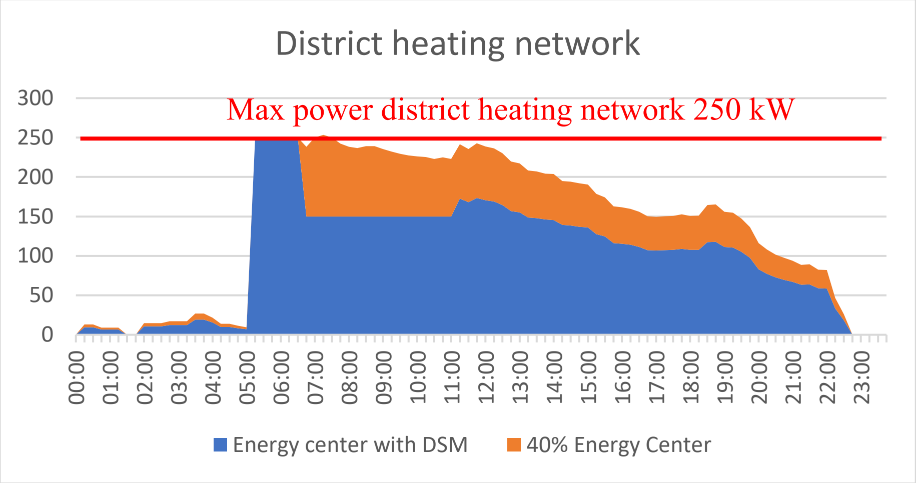


Figure 6-11 DSM application on district heating network

As you can see, the seller cannot sell above his maximum power. So the only way to get more energy is to distribute the load as much as possible in a way that stimulates the DSM strategy

Last but not least is the seller's economic profit reasoning that incentivizes this DSM strategy in fact it is very interesting to note that in the event of saturation in the peak hours of the district heating network; even if the low hourly price requested is only 25%, however the final profit by the energy supplier would be very high from a minimum of 27% to a maximum of 48%.

7. Conclusions

The thesis developed is a thesis of a prevalently economic nature and a subsequent technical-scientific one. For this reason the considerations will be mainly of an economic nature. According to the study conducted, Italy is not one of the countries that uses demand side management the most. However, I think that for this very reason Italy has more advantages than other countries to start making DSM as many technologies and experiments have already been conducted abroad. So starting now means starting from studies already present in the literature and above all with very reliable technologies, an example, the power detectors whose technology has improved a lot in the last 15 years so starting now means starting with cheap and reliable machines.

The thesis dealt specifically with the air conditioning technologies used by the building. A very important achievement of the thesis was to study whether these technologies will still be present in the future or will retire. Surprisingly, it has been estimated that the district heating network in the summer period from 2030 onwards will not be powered, on the contrary in the winter period the district heating network will continue to be powered at least until 2040. This means that the DSM practices studied concern only the use of the multipurpose heat pump and the use of the heat exchanger in winter.

Two DSM optimizations were performed during the study. The first concerns summer air conditioning while the second concerns winter air conditioning. In summer air conditioning, optimization was based on strategic conservation, in other words energy saving. In this strategy, the user or the energy center delays the start of the air conditioning and does not perform post heating to control humidity. This optimization could save up to 60% of energy however it has the limit that it cannot be applied when temperatures exceed 29 C. The second DSM strategy is based on load shifting. In this strategy the peak power has been anticipated and lengthened with the aim of lowering the power required during the hours of maximum demand by 40%. From an economic point of view this strategy is disadvantageous from an energy point of view because heating earlier means dispersing for longer, on the contrary this strategy strongly benefits the supplier because having the free energy peak of 40% would allow the supplier to make a new contract with power required up to 40% of the energy center peak. For this reason the supplier could share some interests with the building which would apply DSM strategies in such a way as to incentivize this type of strategy.

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